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RISK ASSESSMENT DATA EVALUATION REPORT

RADER

FOR THE POPULATED AREAS OF THE BUNKER HILL SUPERFUND SITE

October 18, 1990

Prepared for

U.S. Environmental Protection Agency, Region X

and

Idaho Department of Health and Welfare

Printed on Recycled Paper

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EPA

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FOR THE POPULATED AREAS OF THE BUNKER HILL SUPERFUND SITE

October 18, 1990

Prepared for

Superfund Section - Region X, U.S. Environmental Protection Agency
Sally Martyn, Remedial Project Manager

and

Idaho Department of Health and Welfare
Rob Hanson, Project Manager

under

Sub-contract to SAIC
USEPA Contract No. 68-W9-0008, WA #C10012

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Produced by

CH2M HILL

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1.0 INTRODUCTION

1.1 Project Description

The Bunker Hill National Priorities List (NPL) site is currently in the Remedial Investigation/Feasibility Study (RI/FS) phase of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) process. The designated RI/FS study area encompasses 21 miles of contaminated properties surrounding and including the defunct Bunker Hill primary lead/zinc smelting complex. The site is located in a narrow mountain valley in northern Idaho. Features include the smelter industrial area, a major river drainage polluted by a century of mine waste discharges, several thousand acres of barren and contaminated hillsides and floodplain, and four cities and one unincorporated town housing approximately 5,000 persons. Contaminants of concern include several heavy metals and organics typically associated with non-ferrous mining and smelting activities. Among the most significant are antimony, arsenic, cadmium, copper, lead, mercury, and zinc.

Site characterization has been accomplished to determine the extent of toxic contaminant concentrations in site media and the associated risk to the public health and welfare, and to the environment. The site has been divided into two major portions for RI/FS efforts. This report summarizes the Remedial Investigation (RI) and Risk Assessment (RA) activities undertaken in the *Populated Areas* or those properties within the cities and residential portions of the site.

These communities have a long history of lead-related health problems. The U.S. Environmental Protection Agency (USEPA), the Federal Centers for Disease Control (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR), the Idaho Department of Health and Welfare (IDHW), and the local Panhandle Health District (PHD), have cooperatively conducted a number of investigations, surveys, and medical surveillance activities in the area. Public health and medical follow-up programs have been in place over the last two decades to reduce excess lead absorption among children. During the 1970s, health intervention efforts were directed at reducing exposures related to the operating smelter. The smelter closed in 1981.

The site was designated on the NPL in 1983. RI/FS efforts commenced at this site in late 1984, following completion of the 1983 Lead Health Study. The summary report for that survey, entitled *Kellogg Revisited* (PHD et al., 1986), indicated that a significant portion of the childhood population continued to suffer lead intoxication more than 2 years after closure of the smelting complex. These excess absorptions were related to residual heavy metal contamination found in the area's soils and dust. Throughout the 1980s, health intervention efforts have been directed at reducing exposures to these residual lead sources.

In recognition of the history and complexity of this site, and the continuing need for active health intervention efforts, the State and federal governments negotiated an integrated project structure for RI/FS activities. The site was divided into two principal portions--the Populated and Non-populated Areas. The Populated Areas include the several cities and all residential and commercial properties located within those cities' impact areas. The Non-populated Areas include the smelter complex, river floodplain, barren hillsides, groundwater, air pollution, and industrial waste components of the site.

Separate RI/FS efforts are ongoing in each portion of the site. Region X of the USEPA oversees both. The State of Idaho conducts the Populated Areas RI/FS, and one of the site's Potentially Responsible Parties (PRP) has undertaken the Non-populated Areas investigation. In order to provide continuity and consistency between the RI/FS, Region X USEPA has reserved certain project responsibilities including oversight, risk assessment, cost recovery, enforcement, and interim removal efforts. Figure 1.1 shows the generalized project structure. Geographically the site is divided into two major functional areas that represent the Populated and Non-populated portions of the site. Figure 1.2 shows site location. Figure 1.3 shows the general boundaries of the Populated

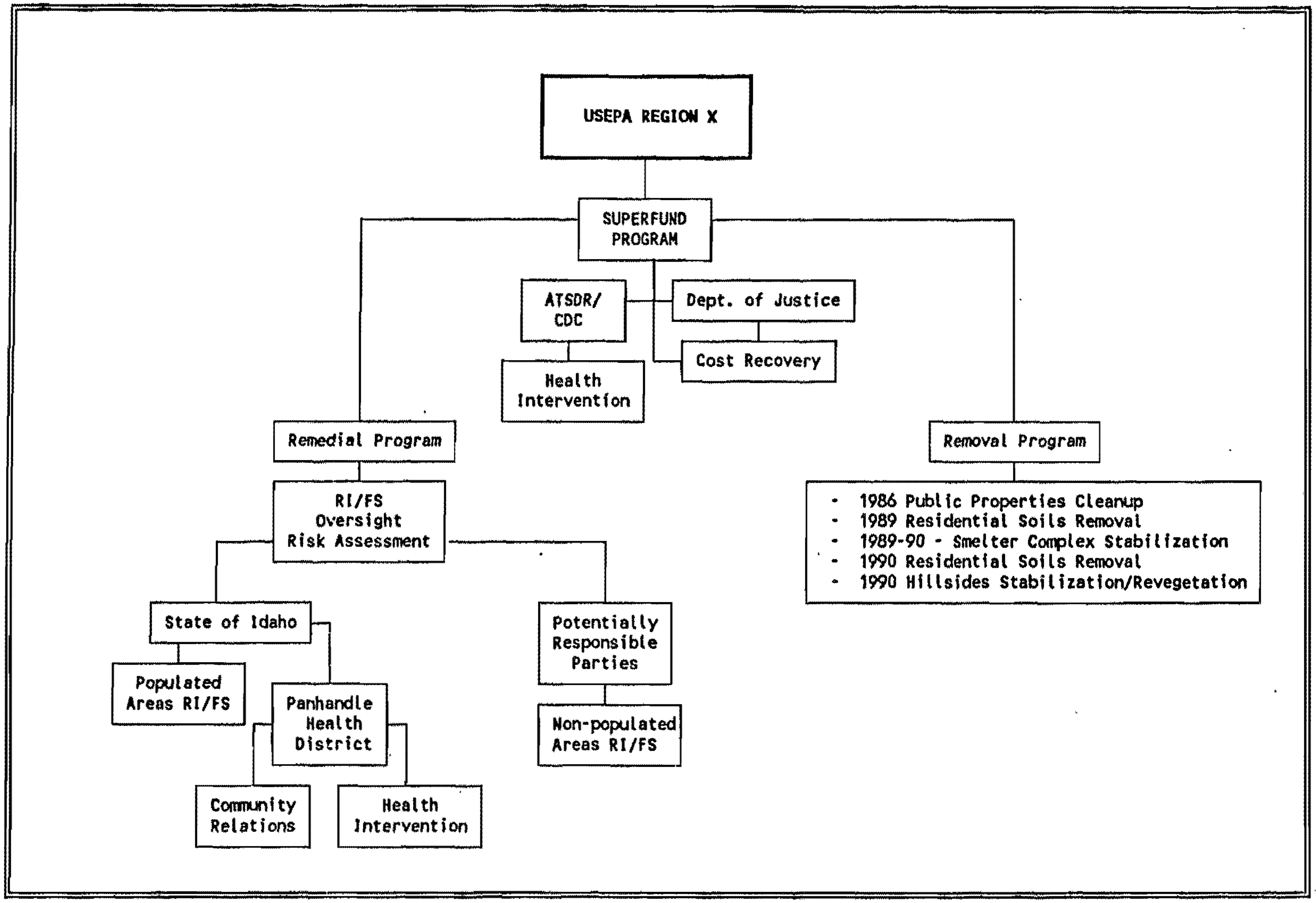

FIGURE 1.1

Bunker Hill NPL Site Project Organization

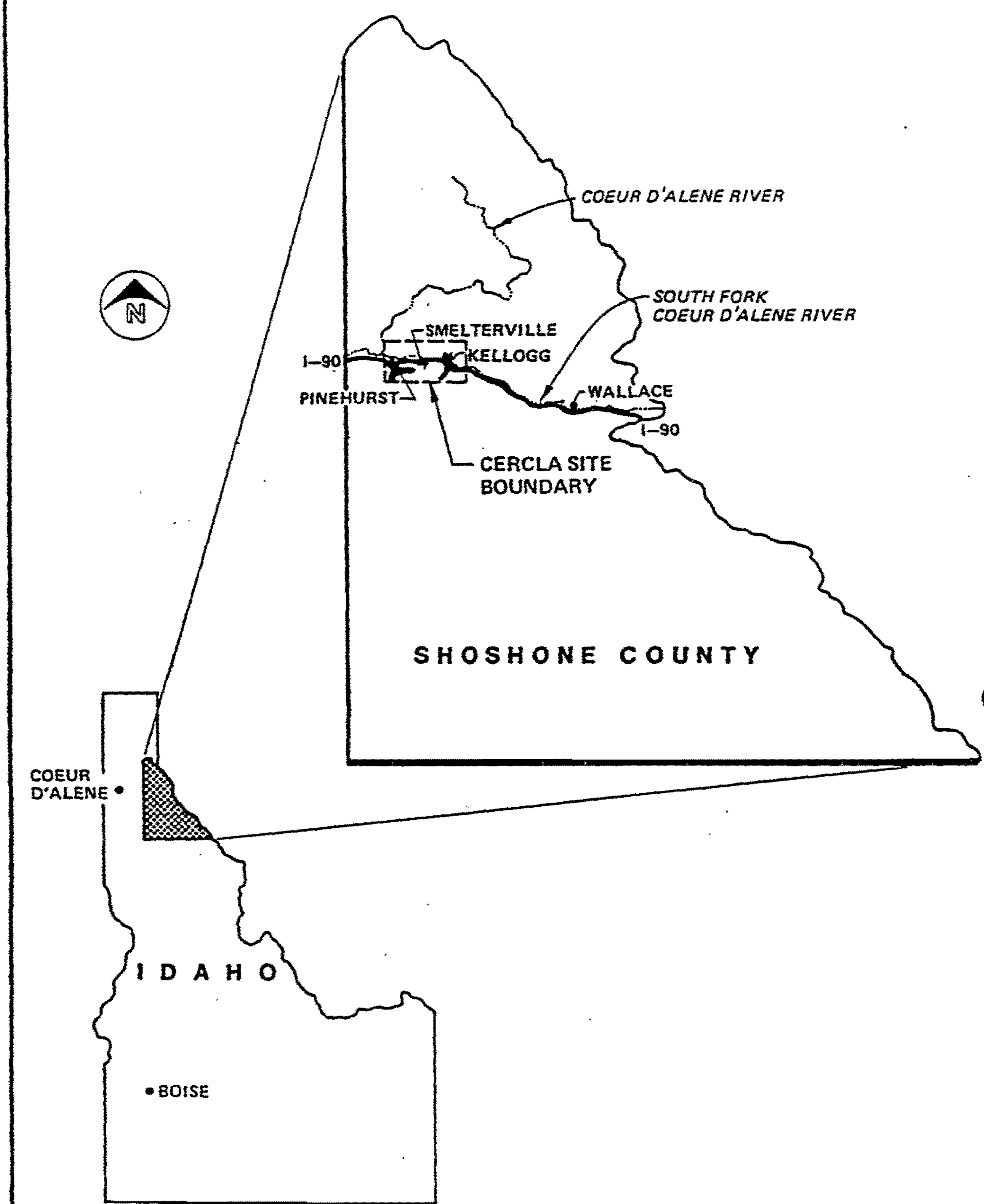

Figure 1.2
BUNKER HILL
CERCLA SITE LOCATION

BUNKER HILL POPULATED AREAS RI/FS

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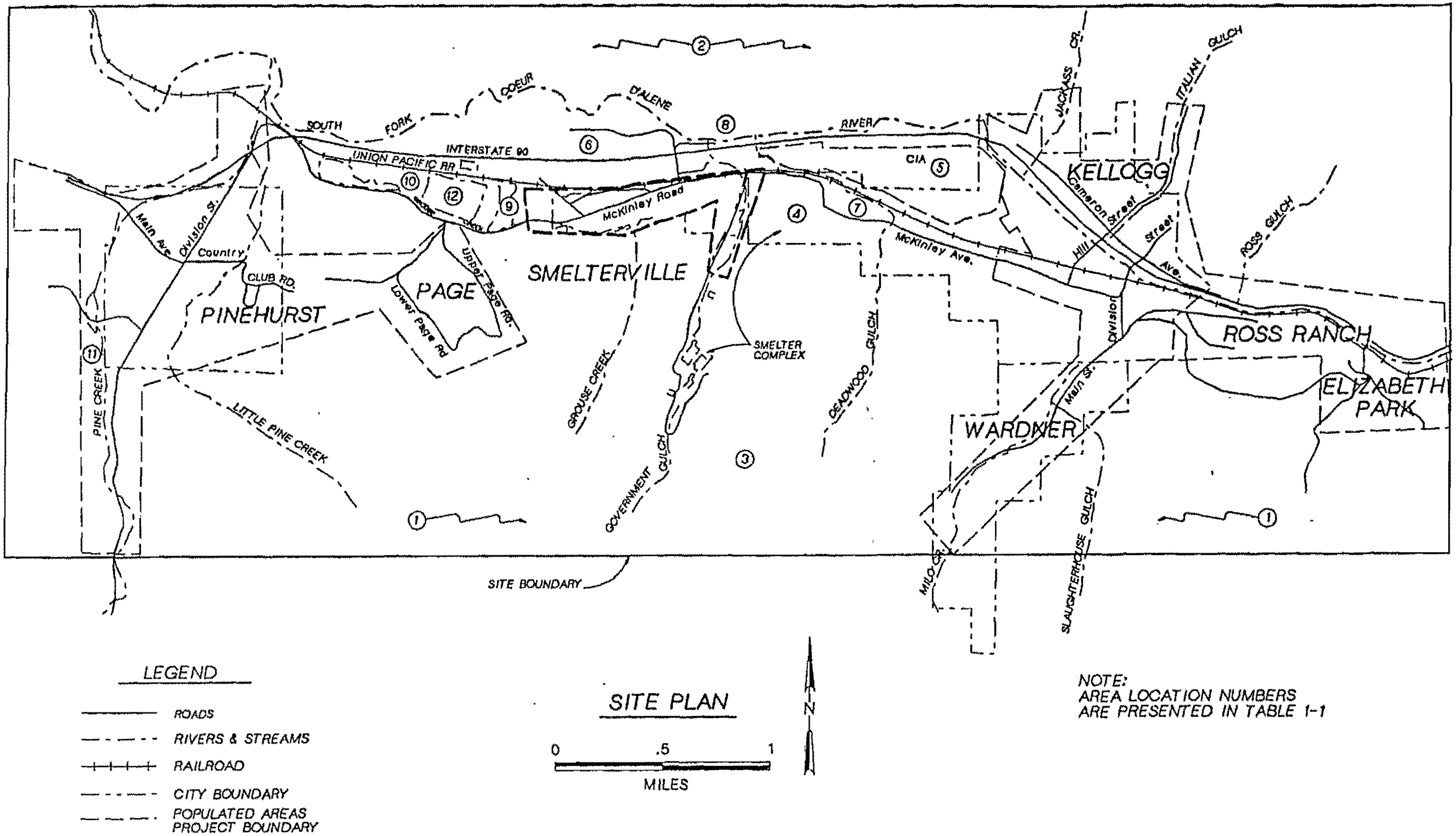

FIGURE 1.3
POPULATED AND NONPOPULATED
AREAS OF THE SITE

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Areas RI/FS and important site study elements and Table 1.1 lists the major study elements and subjects of emphasis within each investigation area.

Table 1.1
MAJOR FEATURES AND INVESTIGATION EMPHASIS

Major Geographic Features

Populated Areas	Non-populated Areas
• Pinehurst	1 North Facing Hillsides
• Page	2 South Facing Hillsides
• Smelterville	3 Denuded Hillsides Near Complex
• Kellogg	4 Bunker Hill Smelter Complex Area
• Wardner	5 Central Impoundment Area (CIA)
	6 Smelterville Flats
	7 Industrial Corridor
	8 River Channel Area
	9 East Page Swamp
	10 West Page Swamp
	11 Pine Creek Channel
	12 Page Pond

Investigation Emphasis

Populated Areas	Non-populated Areas
• Contaminated Soils and Dusts	• Soil and Surface Materials
• Residential Properties	• Surface Water
• Commercial Properties	• Groundwater
• Roadways/Railways	• Air/Atmospheric Transport
• Fugitive Dusts Sources	• Vegetation
• House dust	• Buildings/Process Equipment
• Airborne Contamination	• Waste Piles
	• Buried Wastes
	• Contaminant Migration

Inherent in the Populated Areas effort are numerous individual property and health-related issues. Several hundred private properties have contamination levels that could represent a hazard to human health or the environment. Public health intervention efforts are underway at many of the area homes. A majority of the properties in some cities have been identified as candidates for remediation. In response to immediate health threats, removal efforts have already been undertaken at several locations.

This report presents, summarizes and evaluates the results of the Populated Areas Remedial Investigation and associated health intervention and risk assessment efforts that have been ongoing for the last 5 years. Analyses are performed and conclusions are drawn with respect to site pollutant levels in various media, active and potential contaminant migration pathways, and resultant risk to human health. Recommendations are offered for additional investigatory and Feasibility Study (FS) efforts to facilitate development of remedial actions in the Populated Areas.

1.2 Purpose and Objectives

The primary purpose of the Risk Assessment and Data Evaluation Report (RADER) is to describe the nature and extent of contamination in the Populated Areas and to evaluate associated health risks to the resident population. Public health issues affecting the on-site population are the principal focus of the data evaluations. Additionally, environmental media and transport data are presented and discussed. Further evaluation of this and other information will be accomplished in focused feasibility and remedial design studies. Characterization of occupational exposures to site contaminants and associated risks are not addressed but will be evaluated in the Non-populated Areas Risk Assessment.

The objectives of the RADER are fivefold and include:

- Summary and presentation of the results of the Phase I and II Remedial Investigation results for the Populated Areas.
- Presentation of the results of the Baseline Risk Assessment for the Populated Areas.
- Identification of the potentially significant contaminant transport mechanisms that affect the Populated Areas of the site.
- Identification of actual, and potentially significant, risks to human health and the environment and associated remedial needs.

- Recommendations for additional work to facilitate development of appropriate remedial strategies.

Both historical health and environmental survey information, and site data collected in recent RI efforts are summarized and presented. Emphasis is on those site characteristics that may result in excessive health risk due to direct and indirect exposures to the population. Environmental and health survey data collected since 1971 are used because historical analyses are necessary to assess possible residual and latent health effects associated with past contaminant exposures. These evaluations are especially important for estimating chronic/lifetime exposures to individuals residing in the area during smelter operations. Three primary data sources have been used for this report. Those documents are:

1. Populated Areas RI/FS Data Summary Reports (DSRs) produced for the Idaho Department of Health and Welfare (IDHW)

2. Non-populated Areas RI/FS Data Evaluation Reports (DERs) produced under a USEPA Consent Agreement by Gulf Resources and Chemical Corporation (a site PRP)

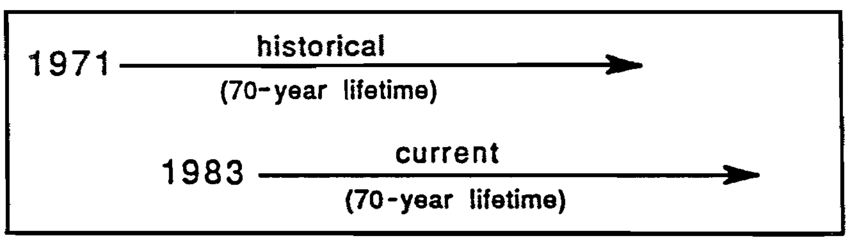
3. *Human Health Risk Assessment Protocol For The Populated Areas Of The Bunker Hill Superfund Site* (PD) (JEG et al., 1989)

The latter document comprehensively summarized pertinent historical health and environmental data from the last two decades and provided a protocol or methodology for Risk Assessment activities for this site. See Appendix A1 for a comprehensive list of all DSRs and DERs.

Health risks to sensitive populations are characterized for both carcinogenic and noncarcinogenic effects due to exposures to seven site contaminants. Those are **antimony, arsenic, cadmium, copper, lead, mercury,** and **zinc.** Organic compound contamination in the Populated Areas tends to be random and at low levels, posing minimal health concerns for the general population. Chlorinated pesticides, however, were found in a preliminary analysis to be present in some residential soils at levels that could pose some health risk. Additional surveys and analyses are currently underway to further characterize pesticide contamination in the Populated Areas.

Both carcinogenic and noncarcinogenic effects of contaminant exposures are evaluated for 70-year (lifetime) exposures in Smelterville, Kellogg/Wardner/Page, and Pinehurst for two baseline periods. For this evaluation, the two baseline periods are defined accordingly:

> Historical--An exposure period for current residents who were born in 1971 and were 2 years old during the period of high site exposures (in 1973) and who remain on site under current conditions for a 70-year lifetime; and
>
> Current--An exposure period for residents who were not exposed during active smelter operations, and who are assumed to live since birth (for a period of 70 years) under current site conditions represented by the contaminant levels found since 1983.



Both of the periods are representative of **baseline** conditions--those conditions under which no remedial action has been undertaken (the no-action alternative).

Exposures and consequent risks are evaluated for each of the two baseline periods in three separate communities for the average or typical population. Additional exposures and risks could be experienced by members of the population who participate in activities that may be considered non-typical, that are evaluated as **incremental** or additional exposures (in addition to that experienced under the baseline analysis for the typical population). Activities evaluated for incremental exposures and risk include the consumption of local garden produce, consumption of contaminated site groundwater, and "pica-type" behavior in children; all are described in detail in Section 5. Population exposures to soils and dusts exhibiting greater than average (or extreme) concentrations of contaminants are also evaluated as an incremental exposure. The evaluation of exposures to soils and dusts at extreme concentrations of contaminants is similar to the analyses performed as an RME (reasonable maximum exposure) under recent USEPA guidance (USEPA, 1989j).

Risk characterization for sub-chronic lead exposures are accomplished by using observed childhood population blood lead levels and environmental media lead concentrations collected over the last seventeen years. An integrated uptake/biokinetic dose-response model is used to relate childhood blood lead levels to contaminated media exposures. Model inputs and criteria are selected and validated using the site-specific data base. Use of the validated model and associated input parameters for evaluation of remedial goals and potential cleanup alternatives for lead contaminated soils and house dusts is discussed.

Applicable or relevant and appropriate requirements (ARARs) and other to-be-considered (TBCs) materials, when available, are presented and compared to the site characteristics. In this report, when ARARs and TBCs are not available, the remedial activities and goals are evaluated against acceptable human health risk criteria. Site environmental and human health survey data are used to determine conformance with federal, State and local laws and regulations as determined in the baseline risk assessment. These results are used to evaluate human health risk, need for remediation, and to support the implementation of selected focused feasibility studies (FFSs). The results of the FFSs will be used for the development of a comprehensive site remedial plan.

1.3 Report Organization

This report is organized and presented in a format consistent with USEPA guidance for RI/FS reports. The material is presented in seven sections briefly described below. In several instances, specific information (such as large data tables and complex analyses) has been incorporated in the Appendices to enhance the readability of the document.

Section 1 - The **INTRODUCTION** presents the objectives of the RADER report and its purpose and role in the site RI plan. Site background, project structure, history, and previous investigations pertinent to the Populated Areas are also summarized in Section 1.

Section 2 - **SITE CHARACTERISTICS** presents and summarizes site data describing the nature and extent of contamination. These results are drawn from various Data Evaluation Reports (DERs) and Data Summary Reports (DSRs) developed in the RI or associated studies that have been conducted in Health Intervention or Interim Remedial Measures efforts. Data presentation is arranged by environmental medium with particular emphasis on those media with potential for direct and indirect exposure to the population in the residential areas of the site. Summary tables and associated statistics are provided to support the baseline human health risk assessment and the development of FFSs. Additional RI data and pertinent references, critical for use in the FFSs, are acknowledged and cited.

Section 3 - **APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS** presents ARARs and TBCs pertinent to the Populated Areas of the site. Site-specific media contaminant concentrations developed in Section 2 are compared to determine site conformance with regulatory standards and health-based criteria. Areas are identified where additional health-based risk analyses are required.

Section 4 - **CONTAMINANT FATE AND TRANSPORT** presents and evaluates potentially significant routes of contaminant migration as they are related to and affect human exposures in the Populated Areas. Migration into and within the Populated Areas are discussed with respect to potential human health risk and planning and engineering considerations to be addressed in Feasibility Studies.

Section 5 - **EXPOSURE ASSESSMENT** quantitatively estimates baseline population exposures to site contaminants of concern by developing intake estimates for particular pathways and exposure routes for sensitive populations. Past, current, and future exposures are evaluated to assess baseline health status of the residential population under a no-action scenario.

Section 6 - **RISK CHARACTERIZATION** estimates baseline and incremental risk to carcinogenic and noncarcinogenic disease resulting from chronic/lifetime and sub-chronic exposures to site contaminants. Critical assumptions and site-specific data are presented and employed for evaluating risk to adverse health effects for sensitive populations.

Section 7 - **CONCLUSIONS AND RECOMMENDATIONS** summarizes those site characteristics that are in nonconformance with chemical-specific ARARs and TBCs, exceedances of target risk levels, and the potential for continued and future releases of contaminants in the Populated Areas. Procedures for determination and selection of health-based remedial goals are presented and discussed. Recommendations are presented to support implementation of selected FFSs for the evaluation of remedial alternatives designed to mitigate exposures in residential areas and to control sources of contaminants prior to the development of a comprehensive site remedial plan.

1.4 Site Background

The material summarized in this subsection has been presented in detail in other project documents. Those include the *Human Health Risk Assessment Protocol for the Populated*

Areas of the Bunker Hill Superfund Site (JEG et al., 1989), the *Interim Site Characterization Report* (WCC & TG, 1986), and the *Soils Characterization Report* (TG, 1986b).

1.4.1 Site Description

The Bunker Hill site is located in Shoshone County, northern Idaho at 47°5', north latitude and 116°10' west longitude (Figure 1.2). The Study Area lies in the Silver Valley of the South Fork of the Coeur d'Alene River (SFCDR) that flows westerly joining the North Fork of the Coeur d'Alene River and terminates at Lake Coeur d'Alene. Interstate Highway 90 crosses the site from east to west, approximately parallel to the SFCDR. The 21-square-mile area is bounded on the west by the town of Pinehurst and on the east by the town of Kellogg (Figure 1.3). The smelter complex occupies several hundred acres in the center of the site between the towns of Kellogg and Smelterville.

The site includes the four incorporated cities of Kellogg, Pinehurst, Smelterville and Wardner that have a combined population of approximately 5,000. Over 100 years of mine waste discharge and 65 years of smelting have occurred at this site. The industrial complex consists of the Bunker Hill Mine producing galena ores, a milling and concentrating operation, a lead smelter, a silver refinery, an electrolytic zinc plant, a phosphoric acid and phosphate fertilizer plant, two sulfuric acid plants and a cadmium plant. In late 1981, most operations at the site ceased. The mine and ore concentrating operation reopened in 1986. The Bunker Hill mine, mill, ore concentrator, and wastewater treatment plant are currently active.

The site contains 160 acres of impounded tailings and several hundred acres of contaminated soils and waste piles. The majority of the unconfined tailings on the site are found in the large river floodplain of the SFCDR. The tailings represent a continuing metal contaminant source to the environment through leaching, runoff and wind-entrained dusts.

The meteorology of the site is dominated by mountain/valley drainage winds related to the local topography. The orientation of the valley effectively channels winds in an east-west direction. Nocturnal winds average 4.5 mph and tend to be from the east. Late morning and afternoon winds are from the west and southwest averaging approximately 8 mph. The mean precipitation of the area ranges from 30.4 inches at Kellogg to 40.5 inches at the nearby city of Wallace, 10 miles east (upstream) of the site.

The vegetation at the site has been severely modified over the past 100 years by a combination of smelter emissions, mining activity, logging and forest fires. The original dense forests have become barren or sparsely vegetated shrub communities. The Bunker Hill Company, as part of a revegetation effort beginning in the early 1970s, identified 18,000 acres requiring reforestation. Although reclamation efforts have been conducted on about 5,000 acres with reportedly good success, much of the site remains sparsely vegetated. Most of the site surface soils have been contaminated by heavy metals, to varying degrees, through a combination of airborne particulate deposition, flooding, and tailings disposal.

1.4.2 Site History

The Bunker Hill Superfund Site is part of the Coeur d'Alene Mining District located in northern Idaho and western Montana. Gold was first discovered in the district in 1883. The first mill for processing lead and silver ores at the Bunker Hill site was constructed in 1886 and had a capacity of 100 tons of raw ore per day. Other mills subsequently were built at the site and the milling capacity ultimately reached 2,500 tons per day.

The Kellogg-based Bunker Hill and Sullivan Mining Company, incorporated in 1887, was the original owner and operator of the Bunker Hill complex. In 1956 the name was changed to the Bunker Hill Company, and in 1968 Gulf Resources and Chemical Company of Houston, Texas, purchased the company and operated the smelter until it was closed in late 1981. The complex was purchased in 1982 by its present owners, the Bunker Limited Partnership, headquartered in Kellogg, Idaho.

The Bunker Hill and Sullivan Mining Company was originally involved only in mining and milling lead and silver ores from local mines. From 1886 until 1917, the lead and silver concentrates produced at the site were shipped to off-site smelters for processing. Construction of the lead smelter began in 1916 and the first blast furnace went on-line in 1917. Over the years, the smelter was expanded and modified. At the time of its closure in 1981, the lead smelter had a capacity of over 300 tons of metallic lead per day. An electrolytic zinc plant was put into production at the site in 1928. Two sulfuric acid plants were added to the zinc facilities in 1954 and 1966, and one sulfuric acid plant was added to the lead complex in 1970. When it was closed in 1981, the zinc plant's capacity was approximately 285 tons per day of cast zinc. A phosphoric acid plant was constructed at the site in 1960 and a fertilizer plant was built in 1965. The primary products from these plants were phosphoric acid and pellet-type fertilizers of varying mixtures of nitrogen and phosphorus.

For most of its operating life, the Bunker Hill complex had few controls on atmospheric emissions, solid waste disposal, or wastewater treatment. Initially, most mines in the district and the smelter complex discharged all liquid and solid residue into the South Fork of the Coeur d'Alene River and its tributaries. The river periodically flooded and deposited the waste materials onto the valley floor. Operation and disposal practices caused deposition of hazardous substances throughout the valley, primarily in the form of heavy metal particulates. Some of the reported heavy metal contamination of the river and groundwater is expected to have resulted from leaching of these deposits through contaminated soils and waste piles.

In recent years some wastes have been shipped off-site for disposal in landfills, however, thousands of tons of sludge, tailings, flue dust, and other wastes remain at the complex. These materials contain high levels of arsenic, lead, zinc, cadmium and other metals.

A 1973 fire in the baghouse at the lead smelter main stack severely reduced air pollution control capacity. Total particulate emissions of about 15 to 160 tons per month, containing 50 to 70 percent lead, were reported from the facility's main stack through November 1974. This compares to emissions of about 10 to 20 tons per month prior to the fire. The immediate effects of increased lead emissions and consequent high atmospheric lead levels were observed in a 1974 public health study that showed epidemic lead poisoning among area children. Smelter emissions were identified as the major source of site contamination and excess absorption in children. Several remedial and health intervention actions to reduce blood lead levels have been implemented at the site since 1974 and are presented in JEG et al., 1989.

In 1977, tall stacks (>600 feet) were added at both the zinc and lead smelters to more effectively disperse contaminants from the complex. These devices decreased sulfur oxides concentrations in the late 1970s. The smelter and other Bunker Hill Company activities ceased operation in December 1981. The mine and ore concentrating operations reopened in 1986. The Bunker Hill mine, mill, ore concentrator, and wastewater treatment plant are currently active.

RI/FS activities were initiated in late 1984. Major interim remedial activities were undertaken as part of this project in 1986, 1989, and 1990. In 1986, several public properties including parks, playgrounds, roadsides, and parking areas were remediated through removal of contaminated soils, replacement, and covering. In 1989, the home yards of more than 100 preschool children and pregnant women were similarly replaced.

Recent enforcement activity in the Populated Areas of the site included the issuance by the USEPA of an Administrative Unilateral Order on May 15, 1990, to Responsible Parties for the performance of the immediate removal and response actions regarding the cleanup of contaminated soils at residential properties within the boundaries of the Superfund site. The justification for the order was based on findings of fact and the release, or threatened release, of hazardous substances that may present imminent and substantial endangerment to the public health or welfare or the environment. Approximately 130 additional home yards will be remediated in 1990 under this order.

Orders have also been issued for interim cleanup activities within the complex and surrounding hillsides in the Non-populated Areas of the site. Details can be found in other project references (USEPA, 1990e; USEPA, 1990f). Figure 1.4 summarizes key elements and accomplishments of the Superfund Process at the Bunker Hill Site.

1.4.3 Past Health Investigations

The emphasis of past studies in the residential areas has been on environmental lead contamination and associated lead absorption in children following reports of epidemic lead absorption and intoxication in area children. Several of these site studies include extensive environmental media and population lead health data. Contaminant metals analyzed in environmental monitoring studies have primarily been arsenic, cadmium, lead and zinc. These data are an outstanding resource offering site-specific dose/response information for use in risk assessment. Historical studies, prior to the site's identification on the NPL in late 1983, have been used for:

- Preliminary site characterization
- Determination of data quality objectives and additional data needs for the RI/FS
- Development of the Populated Areas Remedial Investigation work plan,
- Estimating chronic intakes and consequent health risks associated with past contaminant exposures
- Evaluation of potential health effects of historical metal exposures in the residential community
- Evaluation of site-specific dose/response relationships

A summary of **health concerns and effects** associated with past and present site contaminant exposures is found in the Risk Assessment Protocol Document (PD) (JEG et al., 1989). During the past operations of the Bunker Hill facilities, a variety of hazardous substances, mostly products and by-products of the mining, milling and smelting activities, were released into the surrounding environment. Contaminated air, EPA

FIGURE 1.4

The Superfund Process at Bunker Hill

Region 10 Superfund
1200 Sixth Avenue
Seattle Washington
September, 1990

Study Phase
(Remedial Investigation/Feasibility Study)

Populated Areas:
work being conducted by IDHW and EPA

Report/Studies	Date Completed
Health Intervention Program	1983 (on-going)
Site Characterization	1986
Dust Source Sampling	1986
Community Relations Plan	1987
Residential Soils Sampling	1987
Commercial Soils Sampling	1989
Sample Analyses/Quality Check	1989
Ambient Air Sampling	1989
Sample Analyses/Quality Check	1990
Community Relations Plan Update	1990
Risk Assessment/Data Evaluation Report	1990 *(Fall)*
Residential Soils Feasibility Study	1990 *(Winter)*
House Interiors	1991
Early Actions	
Page Ponds Disposal Area Agreement	1990

Non-Populated Area:
work being conducted by Potentially Responsible Parties (PRPs) with EPA oversight.

Reports/Studies	Date Completed
Groundwater evaluation	on-going
Air modeling	on-going
Smelter Complex Investigation	on-going
Disposal Area Evaluation	on-going
Ecological Risk Assessment *	1991
Remedial Investigation	1991
Human Health Risk Assessment *	1991
Feasibility Study	1992
Early Actions	
Smelter Complex Removal Order	1989
Smelter Complex Short-term Stabilization	1989/1990
Hillsides Revegetation/Stabilization Order	1990

** Indicates EPA is conducting work and will recover cost from PRPs.*

Decision Phase
(Record of Decision)

Populated Areas

Residential Soils	early 1991
House Interiors	early 1992
Commercial Properties	early 1992

Non-Populated Area

CIA, Hillsides, Smelter Complex, groundwater, river and flats	1993/1994

These decisions could occur earlier under enforcement actions

Other Activities	Dates Completed
Gondola Prospective Purchaser Agreement	1988
Recovery of Costs for 1986 Parks/Playgrounds Soils Removal	1989
Cooperative Agreement with Couer d'Alene Tribe	1990
Prepayment by PRPs for 1990 Soils Removal	1990

Early Cleanup Actions in Populated Areas

Parks and Playground "Fast Track" Removal ***(16 Sites Completed)***	1986
Residential Soils Removals ***(83 Residences Completed)***	1989
Residential Soils Removals ***(138 Residences Completed)***	1990

Cleanup Phase
(Remedial Design/Remedial Action)

Populated Areas

Residential Soils	Start 1992

Non-Populated Area

Dates for activities in this area are dependent on completion of decision phase

Remedial Investigation/ Feasibility Study → **Record of Decision** → **Remedial Design/ Remedial Action**

soils, and dusts have been identified as contributors to elevated blood lead levels in children living in the Bunker Hill project area. Environmental media concentrations of site contaminants of concern in the Populated Areas are strongly dependent on distance from the smelter facility and industrial complex. Residential areas nearest the smelter complex have shown the greatest air, soil and dust lead concentrations; the highest childhood blood lead levels; and the greatest incidence of excess absorption in each of the studies conducted in the last decade.

During the period 1974 through 1990, childhood blood lead levels in the area have ranged from approximately 1 μg/dl to a high of 164 μg/dl. The highest areawide blood lead levels for children $\leq$ 9 years were reported in 1974 (median = 46 μg/dl) and the lowest in 1990 (median = 8 μg/dl). Two years after smelter closure, in 1983, more than 25% of preschool children in the most contaminated area of the site exhibited blood lead levels greater than 25 μg/dl. It is estimated that since 1973 more than 1,000 children in this community have experienced excessive absorption of lead (relative to the current CDC 25 μg/dl criteria) and possibly other metals (JEG et al., 1989).

The health effects of environmental contamination were first documented following the period of extreme smelter emissions in 1973 and 1974. Up to 75% of the preschool children tested within several miles of the complex had blood lead levels exceeding CDC criteria. Several local children were diagnosed with clinical lead poisoning and required hospitalization. Lead health surveys conducted throughout the 1970s confirmed that excess blood lead absorption was endemic to this community. Concurrent epidemiologic and environmental investigations concluded that atmospheric emissions of particulate lead from the active smelter were the primary sources of environmental lead that affected children's blood lead levels prior to 1981. Contaminated soils were also found to be a significant, however secondary, source of lead to children in the 1970s.

An analysis of historical exposures to children who were 2 years old in 1973 suggests a high risk to normal childhood development and metal accumulation in bones due to extreme exposures that could offer a continuing lead body burden in these children due to its long physiologic half life. Females who were 2 years of age during 1973 are now of child-bearing age, and even with maximum reduction in current exposure to lead, the fetus may be at risk due to resorption of bone lead stores in the young women (JEG et al., 1989).

Following smelter closure in late 1981, airborne lead exposure decreased by a factor of 10, from a sitewide average of approximately 5 $\mu g/m^3$ to 0.5 $\mu g/m^3$. A 1983 survey of children's blood lead levels demonstrated a significant decrease in community exposures to lead contamination. The survey also found that several children, including some born since 1981, continued to exhibit blood lead levels in excess of recommended public health criteria. Accompanying epidemiological analyses suggested that residual contamination in soils and dusts represented the most accessible sources of environmental lead in the community. The potential hazard presented by these sources and the indication of continued health risk experienced by the community were major considerations in the USEPA's and IDHW's decision to initiate RI/FS activities for the Bunker Hill project area.

Childhood mean blood lead levels have continued to decrease since 1983. These decreases are likely related to a nationwide reduction in dietary lead; reduced soil, dust and air levels in the community; intake reductions achieved through denying access to sources; and the increase in family and personal hygiene practiced in the community. The latter is reflected in the implementation of a comprehensive Community Health Intervention Program in 1984 that encourages improved hygienic (housekeeping) practices, increased vigilance, parental awareness and special consultation on individual source control practices such as lawn care, removals, and restrictions. The Community Health Intervention Program was initiated specifically to reduce the potential for excess absorptions and minimize total absorption in the population until initiation of remedial activities. Total blood lead absorption among the community's children has been reduced nearly 50% since 1983. The incidence of lead toxicity (blood lead > 25 µg/dl) has fallen from 25% to less than 5% of children in the highest exposure areas.

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2.0 SITE ENVIRONMENTAL MEDIA CHARACTERISTICS

In this section, the results of environmental media sampling and monitoring studies for both RI efforts are presented. Additional Non-populated Areas RI and historical health study data used in later analyses are also introduced in Sections 4, 5, and 6. Site characteristics with potential for adversely affecting public health and welfare are emphasized. The environmental media concentrations are used in Section 5 to perform an integrated exposure analysis for the current residential population. Exposure analyses are, in turn, used to assess public health risk and the potential for site-specific disease. The results of the risk assessment ultimately supports the development of focused feasibility studies and the need for remedial activities at the site. Analysis techniques, exposure pathways, contaminants and media of concern, and receptor populations have been identified and described in detail in JEG et al., 1989.

Contaminants of concern for the Populated Areas were identified and selected according to three criteria: 1) elevated concentrations in residential soils and dusts relative to background concentrations; 2) decreasing concentrations in environmental media with increasing distance from the industrial complex; and 3) potential for human toxicity following incidental and chronic exposures. Contaminant metals satisfying these criteria and used in the exposure analyses include **antimony, arsenic, cadmium, copper, lead, mercury,** and **zinc.**

Past health and risk assessment investigations have identified the principal environmental media for this evaluation. Those media are residential area surface soils, interior house dusts, fugitive dust sources, air particulate matter, and groundwater (from wells within or adjacent to boundaries of the Populated Areas). The following subsections in this chapter address each of the principal media except groundwater. Groundwater concentrations are provided in Section 3. Additional media requiring integration in the site exposure evaluation include market basket variety produce, public water supplies, local garden produce, and locally caught fish (within the proximity of Lake Coeur d'Alene). These latter media are evaluated in Sections 5 and 6 as components of the risk assessment.

Results of all site investigations in the residential areas are treated as confidential data. This requirement results in the classification and grouping of residential yard soil, house dust, and blood lead values according to geographic areas. Early investigations divided the site into geographic areas 1, 2, and 3 representing the communities of Smelterville; Kellogg/Wardner/Page; and Pinehurst, respectively (Landrigan et al., 1975 and 1976). These groupings were based on elevated childhood lead absorption in 1974 and the correlation exhibited between environmental media concentrations, children's blood lead levels, and distance from the lead smelter facility. Results presented in this section are organized in a similar manner with the exception that some neighborhood characterization of soil contaminant levels based on legal subdivisions is presented in Section 2.1.

2.1 Soils

Sampling of contaminated soils in the RI/FS Area has been conducted in periodic surveys since 1974. Table 2.1 shows historical soil surveys that were available at the beginning of RI/FS efforts in 1985. These data were analyzed and discussed in previous site documents (TG 1986b and JEG et al., 1989).

Several soils investigations have been undertaken in the RI efforts for this site. Data collected to assess contaminant distributions in surface soils in the Populated Areas include residential yards, parks, playgrounds, commercial properties, roadsides, railroad right-of-ways, and fugitive dusts sources (barren areas). Limited subsurface (contaminants-of-depth) sampling and waste characterization analyses (leachate testing) have been conducted at these sites as well. Results of these studies are presented in this section.

Table 2.1
Selected Soil Studies

Study	Depth(in)	Site Within Project Area	Chemical Data	Range of Values (ppm for metals)
IDHW Phase I (1974)	0.5	22	Lead	125-9,000
Contact Soil/Play Areas		22	pH	4.5-6.6
IDHW Phase II (1974)	0-0.5	69	Lead	62-23,600
Valley Wide Profiles	0.5-1.5	68	Cadmium	1.8-236
	1.5-3	69	pH	3.3-7.0
IDHW Phase III (1974)	0.5	194	Lead	84-24,600
City Residential		192	Cadmium	2.8-210
		192	Zinc	61-8,000
		192	Arsenic	1-258
		189	Antimony	2-350
		189	Mercury	0.5-310
PedCo (1975) Valley-Wide Fugitive Dust Sources	0.5	13	Lead	1,000-33,000
IDHW Homesites (1975)	0.5	84	Lead	126-15,200
City Residential		84	Cadmium	2-124
		84	pH	4.5-7.3
IDHW Homesites (1977)	0.5	10	Lead	199-9,643
City Residential		10	Cadmium	2-136
IDHW Passive Areas	0.5	30	Lead	1,000-52,923
(1977)		21	Cadmium	10-506
PES (1979)	0.5	29	Lead	500-36,983
Valley Wide Fugitive Dust Areas		26	Cadmium	1-319
IDHW Passive Areas (1979)	0.5	14	Lead	540-5,720
IDHW Homesites	0-6	64	Lead	34-41,200
Profiles (1983)	1" increments	64	Cadmium	<1.0-475
		64	Zinc	103-11,040
IDHW Homesites (1983)	1	226	Lead	53-41,200
City Residential		232	Cadmium	4-510
		232	Zinc	62-9,847

Adapted from TerraGraphics, 1986b.

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The Non-populated Areas RI effort has characterized both surface and subsurface soil contamination in areas outside the cities. These data include samples from the smelter complex, hillsides, and river floodplain. These results are not presented in this chapter, but are briefly discussed in Section 4 of this document (see Table 4.12 for Non-populated Areas RI Tasks).

Soil sampling has been conducted in both phases of the Populated Areas RI. Phase I RI efforts conducted in 1985-87 included:

- 1986 "Fast Track" Sites for Interim Remedial Measures--Publicly accessed sites suspected as sources of direct contact lead exposure or fugitive dusts
- 1986-87 Residential Soil Survey--Residential properties in Smelterville, Kellogg, Wardner, and Page
- 1986 Fugitive Dust Sources--Major barren areas and waste piles on the valley floor
- 1987 Residential Soil Cores

Phase II efforts included:

- EPTox and TCLP testing of residential soils
- Resampling of 1986 Fast Track Sites
- Selected residential yard sampling for mercury and organics screening
- 1989 Residential Soil Survey--Residential properties in Pinehurst and Elizabeth Park
- Commercial properties
- House and school building interior dust
- Street shoulders
- Railroad right-of-ways

2.1.1 1986 Interim Remedial Measures (Fast Track)

2.1.1.1 The 1986 Removal Action

The 1983 Health Study (PHD, 1986) indicated that residual soil and dust contamination were the primary sources of excessive lead intake among children. Based on these results, and working with local officials, initial soil sampling and remedial efforts in the project area were directed at public access areas frequented by children. This action was referred to as Interim Remedial Measures (IRM) or "Fast Track" Activities. In order to provide local input to the overall Superfund effort at the Bunker Hill site, the Shoshone County Commission organized the Silver Valley Superfund Advisory Task Force. The Task Force, made up of local citizens, first met in May of 1985 to discuss the selection of high priority sites within the Bunker Hill project area. Local public works and elected officials were subsequently requested to develop a list of publicly accessed sites that might present a hazard to young children via exposure to contaminated soils or blowing dust.

Fifty-eight sites were identified as barren or dusty play areas or potential sources of windblown dust that could impact young children in Kellogg, Wardner and Smelterville. Twenty-nine of these sites, believed to be publicly owned, were selected for sampling and analysis and considered for remedial action. Surface soil composite samples were collected from each of these sites. Top-inch mineral soils results for those sites eventually remediated are shown in Table 2.2. Most of these sites had soil lead levels in excess of the CDC warning statement, suggesting that concentrations in excess of 500 to 1,000 μg/gm lead could result in excess absorption in young children (CDC, 1985).

These results were applied in combination with other criteria to rank the several sites for cleanup priority. The criteria included:

- Intensity of site use by children

- Level of soil contamination based on concentration and toxicity of the contaminants, and potential for direct contact exposure
- Potential as a source of windblown dust based on a vegetative cover, size of site and soil particle size
- Size of childhood population residing nearby or regularly using the site

Table 2.2

LEVELS OF HEAVY-METAL CONTAMINATION
BUNKER HILL FAST TRACK SITES - IDAHO

Site and Name		Soil Sampling Results (Highest measured value in µg/gm) Lead	Cadmium	Zinc
Kellogg Sites				
K1	Teeters Field	2863	25	1310
K2	Station Avenue	11100	189	9500
K4	Memorial Park-Little League Field	2278	37	1950
K5	Junior High School Little League Field	605	10	430
K7	Old Highway 10 Shoulders	2410	20	10800
K8	Memorial Park-Playground Area	2563	27	851
K9	Riverside Park	1205	10	485
K10	Gold Street Park	216	1	207
Wardner Sites				
W1	Main Street Shoulders	2237	15	14600
W2	Old Wardner School	2560	32	5830
W3	Lot Adjacent to Wardner School	5230	6	1170
Smelterville Sites				
S1	Silver King School	14500	93	13200
S2	McKinley Avenue Shoulder	24000	126	26800
S3	City Park - Grassed Area	844	11	427
S4	City Park - Barren Play Area	8370	80	4730
S5	Turnout - West of City Park	6150	36	9340
S9	Washington Street Shoulders	3960	42	3980

Adapted from Weston, 1986.

The Bunker Hill Fast Track sites were subsequently divided into two groups of 20 high priority sites and 9 lower priority sites. Seven of the sites were deleted from the initial remedial action list following input from the local Task Force. Preliminary engineering alternatives and cost estimates for remedial measures were then developed for the remaining 22 sites. The 16 sites listed in Table 2.2 were remediated in the summer of 1986. Remedies included a 6-inch removal of contaminated soils and replacement with clean materials and sod in parks and playgrounds, and asphalting or gravel cover of roadsides and parking lots. A summary of the 1986 Fast Track effort can be found in Weston, 1986.

2.1.1.2 Recontamination Studies

Two efforts have been undertaken to assess recontamination at those IRM sites since the summer of 1986. The remediated properties included several publicly-owned parks, playgrounds, roadsides and school yards. In August of 1988, two years after remediation, one of the site PRP's collected surface material composites from the several sites and compared the results to the pre-remediation contamination levels used by the USEPA and IDHW in evaluating the site for remediation in 1986 (Dames & Moore, 1989a). Maps and photographs were used to identify the exact locations where the soils were replaced and sample points were located that best represented each area. Four types of sampling surfaces were identified by Dames & Moore (1989a) as follows:

1. Bare Soils - The top 1/8 inch of soil was collected using a stainless steel trowel and placed in a whirlpac.

2. Vegetated Soils - Litter and surface soil to 0.5-inch deep were collected using a trowel and placed in a whirlpac. Live grass samples were collected using stainless steel scissors and placed in a whirlpac. Thatch (dead grass) was collected by hand and placed in a whirlpac. Thatch formed a mat over the litter layer.

3. Gravel (or bark) - Gravel (or bark) was placed onto a No. 200 mesh sieve screen using a stainless steel trowel. The screen was shaken and the dust and soil particles were collected in a stainless steel pan. Dust and soil particles were placed in a whirlpac and sealed.

4. Paved Areas - Samples were collected by sweeping soil into a dust pan using a fine-hair paintbrush and placed in a whirlpac.

At the laboratory, the minus 200 mesh fraction was separated from the soil and litter samples by sieving. This was performed to isolate the fine particle fraction that might best represent dust deposited on the soil. The samples were analyzed for the following metals: antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc.

Some of these same sites also were sampled in Phase II of Populated Areas RI/FS in the summer of 1989 to evaluate the extent of recontamination at the surface and at the interface of the clean replacement soil and the original subsurface (CH2M HILL, 1990d). Six sites were selected where 6-inch soil removals, replacement with clean soils and sodding was the selected remedial alternative. Soil cores were collected and then sampled from five soil profile intervals in this effort. Those depths included:

1. Litter (where present)
2. 0-1 inch of soil
3. Middle of fill material
4. Bottom of fill material
5. Top of cut (original base material).

Table 2.3 summarizes the original (pre-remediation) concentrations, remedial material (clean fill) concentrations, and the two recontamination assessment efforts for lead at the "Fast-Track" remedial sites. Appendix A2.1 shows complete metal results for both efforts.

The few litter samples that were collected suggest recontamination rates of 10 to 100 $\mu g/gm/yr$ lead. No recontamination was evident in either the top inch or middle of the soil fill on sodded sites or play fields. Some recontamination was evident at the interface of replaced soils and top of the original cut. Whether this was due to contaminant migration, mixing at the time of placement, or imprecise layering of the sample is unknown.

Table 2.3
1986 Fast-Track Site Remediation Efforts and Lead Recontamination Surveys

Site	1985 USEPA/IDHW Pre-remediation Levels	Remedial Action(a)	Recontamination Surveys: 1988 Dames & Moore, 1989a Sample Results		Recontamination Surveys: 1989 CH2M HILL, 1990d Sample Results			
						Core	Core	Core
Wardner School Ball Park Wardner - W2	2560 ppm	6" removal replacement and sodding	North Sodded Area		Sodded Area	1	2	3
			Grass	3.9 ppm Pb	Litter	114 ppm	235 ppm	71 ppm
			Litter	21 ppm Pb	0-1 Inch	22 ppm	41 ppm	43 ppm
			Soil	37 ppm Pb	Middle Fill	57 ppm	42 ppm	32 ppm
			Thatch	23 ppm Pb	Bottom Fill	143 ppm	56 ppm	225 ppm
					Top of Cut	25100 ppm	5330 ppm	3500 ppm
			Southside					
			Grass	4.2 ppm Pb				
			Litter	21 ppm Pb				
			Soil	41 ppm Pb				
			Thatch	41 ppm Pb				
						Core	Core	Core
Parking Lot Wardner - W3	5230 ppm	6" removal replaced and covered with gravel	Gravel & Dirt		Parking Lot	1	2	3
			North Side	210 ppm Pb	0-1 Inch	369 ppm	87 ppm	100 ppm
			Duplicate	111 ppm Pb	Middle Fill	74 ppm	18 ppm	3170 ppm
			South Side	1720 ppm Pb	Bottom Fill	260 ppm	71 ppm	4230 ppm
					Top of Cut	2850 ppm	4850 ppm	603 ppm

Table 2.3 (Continued)
1986 Fast-Track Site Remediation Efforts and Lead Recontamination Surveys

Site	1985 USEPA/IDHW Pre-remediation Levels	Remedial Action(a)	Recontamination Surveys: 1988 Dames & Moore, 1989a Sample Results		1989 CH2M HILL, 1990d Sample Results			
Washington St. Smelterville - S9	3960 ppm	6" removal asphalted	Dust from Asphalt	3240 ppm Pb	No Sampling			
			Gravel from Shoulder					
			North Side	998 ppm Pb				
			South Side	1210 ppm Pb				
City Park Smelterville - S4	8370 ppm (in Playground area)	Playground 6" removal covered with bark chips			Playground	Core 1	Core 2	Core 3
			Dust from Tennis Court(b)	17800 ppm Pb	Bark	552 ppm	1020 ppm	489 ppm
			Playground Bark Chips	792 ppm Pb	Middle Fill	403 ppm	19 ppm	32 ppm
					Bottom Fill	128 ppm	148 ppm	169 ppm
					Top of Cut	3510 ppm	4910 ppm	4410 ppm
City Park (Continued) Smelterville - S5		Turnout Asphalted	Turnout Dust from Asphalt	2840 ppm Pb	No Sampling			

Table 2.3 (Continued)
1986 Fast-Track Site Remediation Efforts and Lead Recontamination Surveys

Site	1985 USEPA/IDHW Pre-remediation Levels	Remedial Action(a)	Recontamination Surveys: 1988 Dames & Moore, 1989a Sample Results			Recontamination Surveys: 1989 CH2M HILL, 1990d Sample Results
McKinley Ave Smelterville - S2	24000 ppm	6" removal and gravel fill	Road Shoulders Gravel			No Sampling
			West End-North	1930	ppm Pb	
			West End-South	3230	ppm Pb	
			Middle-North	3480	ppm Pb	
			Middle-South	2740	ppm Pb	
			East End-North	3820	ppm Pb	
			East End-South	2620	ppm Pb	
Gold Street Park Kellogg - K10	216 ppm	6" removal replace with pea gravel	Pea Gravel			No Sampling
			Near Fence	1320	ppm Pb	
			In Disturbed Area	438	ppm Pb	
Riverside Park Kellogg - K9	1205 ppm	6" removal and replace	Soil			No Sampling
			West Side	35	ppm Pb	
			Monkey Bars	56	ppm Pb	
			Slide	37	ppm Pb	
			Swings	33	ppm Pb	
Station Avenue Kellogg - K2	11100 ppm	Removal to base and gravel cover	West End-North	514	ppm Pb	No Sampling
			West End-South	408	ppm Pb	
			East End-North	317	ppm Pb	
			East End-South	339	ppm Pb	

Table 2.3 (Continued)
1986 Fast-Track Site Remediation Efforts and Lead Recontamination Surveys

Site	1985 USEPA/IDHW Pre-remediation Levels	Remedial Action(a)	Recontamination Surveys: 1988 Dames & Moore, 1989a Sample Results		1989 CH2M HILL, 1990d Sample Results	Core 1	Core 2	Core 3
Teeters Field Kellogg - K1	2863 ppm	6" removal and replacement of infield area	Infield	70 ppm Pb	Infield			
			Backstop	306 ppm Pb				
			Duplicate	70 ppm Pb	0-1 Inch	22 ppm	77 ppm	43 ppm
					Middle Fill	34 ppm	52 ppm	9 ppm
					Bottom Fill	120 ppm	188 ppm	373 ppm
					Top of Cut	4130 ppm	5500 ppm	8350 ppm
Memorial Park Kellogg - K4	2278 ppm	6" removal Infield replaced	Infield	138 ppm Pb	Playground Ar			
			Road(b)	648 ppm Pb				
			South Gravel(b)	8800 ppm Pb	Litter	-- ppm	173 ppm	-- ppm
			North Gravel(b)	450 ppm Pb	0-1 Inch	25 ppm	26 ppm	15 ppm
		Play areas 6" removal and replaced	Playground	80 ppm Pb	Middle Fill	10 ppm	10 ppm	9 ppm
					Bottom Fill	324 ppm	25 ppm	26 ppm
					Top of Cut	1770 ppm	275 ppm	509 ppm
					Infield			
					0-1 Inch	48 ppm	51 ppm	34 ppm
					Middle Fill	23 ppm	8 ppm	9 ppm
					Bottom Fill	19 ppm	15 ppm	40 ppm
					Top of Cut	921 ppm	2040 ppm	1760 ppm

(a) Clean soil lead concentrations 19-86 ppm.
Clean bark lead concentrations 28 ppm.
(b) Site not remediated.

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Graveled areas, particularly those used as parking lots, showed significant recontamination. Because of the low rates of surface deposition, these increases likely resulted from the continual working of the original soil layers below the replacement materials or tracking of contaminants onto the site by vehicles.

2.1.2 Residential Soils

2.1.2.1 1986-87 Residential Soil Survey

Extensive sampling of yard soils for the RI/FS was initiated in the 1986-87 Residential Soil Survey. The communities of Smelterville, Kellogg, Wardner and Page were surveyed in Phase I RI efforts 1986-87. Pinehurst and the additional residential area of Elizabeth Park (immediately east of the project boundaries) were completed in 1989 in part of the Phase II RI.

In both surveys, properties were tracked according to Shoshone County property tax records. Maps and master lists of all properties in each municipality were obtained in advance of survey activities. Every home in the Phase I communities was targeted for sampling. Field crews attempted to contact each homeowner/resident to obtain permission to sample. If permission to sample was granted, samples were secured. If the homeowner or resident refused, the response was noted and the property was bypassed. If the homeowner or resident could not be contacted in three successive visits or if the home was vacant, the property was bypassed.

A composite mineral soil and litter sample was collected from pre-selected locations in each yard. Eight 3/4-inch-diameter soil cores were obtained, four from each of the front and backyards. Samples of the top one inch of mineral soil and litter (decaying vegetative material and sod above the mineral soil horizon) were composited separately for laboratory processing. Samples were processed according to current EPA Contract Laboratory Program (CLP) procedures and analyzed for the following metals: **antimony, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium** and **zinc.**

Details of the sampling and laboratory protocols can be found in TG, 1986c; CH2M HILL, 1990a; and TG, 1990.

In total, more than 64% of all homes in the Phase I communities were sampled in the 1986-87 survey. Table 2.4 summarizes metals concentration by town for the 1986-87 survey for soils and litter. Figure 2.1 shows the frequency distribution for soil lead levels for each community. More than 85% of the properties in these four cities exceed the 500-1,000 μg/gm lead warning criteria cited by CDC for lead in soils (CDC, 1985). Current directives advise using 500 to 1,000 μg/gm lead in soil as a cleanup criteria in the absence of site-specific dose-response information (USEPA, 1989a). Approximately, 1,000 to 1,250 homes in Phase I communities are candidates for eventual remediation by this criteria.

Residential soil survey data were prepared at community meetings in October of 1988. Homeowners and residents were notified of their individual property results and invited to a public forum for further explanation and discussion. For public presentation, it was necessary to use maps and displays that contained no identifiable individual results. To meet that confidentiality requirement, neighborhoods based on legal subdivisions were defined and summary statistics were developed for geographic areas within the cities. Figures 2.2 and 2.3, show non-confidential maps developed to publicly present residential yard soil contamination levels for Smelterville and Kellogg. Table 2.5 shows the overall summary tables from these maps for Smelterville, Page, Wardner, and Kellogg.

There are 2,236 total parcels and 1,547 homes in these areas; 1,020 (64%) of the homes were sampled in the 1986-87 effort. In order to present health risk concepts and to provide citizens with an idea of how their individual results compared to their neighbors and possible health criteria, properties were summarized according to three categories of risk based on soil lead concentrations. Table 2.5 shows, per the example criteria, that 5% of the homes in Smelterville had acceptable soil concentrations (<500 μg/gm Pb), 14% were recommended for individual consideration (500-1,500 μg/gm Pb), and 81%

Table 2.4

SUMMARY OF 1986/87 RESIDENTIAL SOIL METAL CONTAMINATION LEVELS - PHASE I COMMUNITIES

SMELTERVILLE

Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, µg/gm, dry wt. (µg/gm)							
As	litter layer	75	68	63	175	7	366	196	-
	mineral soil	59	55	52	126	3	254	200	< 10
Cd	litter layer	95	81	80	225	5	430	196	-
	mineral soil	41	34	33	101	2	208	200	0.8
Cu	mineral soil	101	88	87	215	11	371	200	28
Hg	mineral soil	6	5	4	18	0.4	50	199	0.1
Pb	litter layer	6440	5560	5190	15900	276	46500	196	-
	mineral soil	3580	3010	2690	10400	202	16100	200	43
Sb	mineral soil	16	12	11	34	1	559	200	1
Zn	litter layer	1710	1590	1520	3430	256	7740	196	-
	mineral soil	914	852	774	2185	134	4220	200	95

KELLOGG*

Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, µg/gm, dry wt. (µg/gm)							
As	litter layer	53	49	48	94	5	285	767	-
	mineral soil	59	54	53	109	4	267	771	< 10
Cd	litter layer	42	40	38	76	3	160	767	-
	mineral soil	23	21	20	46	1	113	771	0.8
Cu	mineral soil	85	73	73	166	1	1280	771	28
Hg	mineral soil	4	3	3	8	0.3	14	771	0.1
Pb	litter layer	3560	3310	3084	6840	146	12600	767	-
	mineral soil	2796	2440	2265	6050	123	17800	771	43
Sb	mineral soil	12	10	9	25	1	164	771	1
Zn	litter layer	1225	1110	1117	2270	194	7800	767	-
	mineral soil	851	741	733	1840	139	3860	771	95

* Includes Ross Ranch

Table 2.4 (Continued)

SUMMARY OF 1986/87 RESIDENTIAL SOIL METAL CONTAMINATION LEVELS - PHASE I COMMUNITIES

WARDNER

Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, $\mu g/gm$, dry wt. ($\mu g/gm$)							
As	litter layer	39	33	35	73	12	102	92	-
	mineral soil	53	47	46	110	14	248	92	< 10
Cd	litter layer	18	18	16	40	2	51	92	-
	mineral soil	13	12	11	29	2	33	92	0.8
Cu	mineral soil	79	60	63	167	17	805	92	28
Hg	mineral soil	2	2	2	6	0.2	6	92	0.1
Pb	litter layer	1720	1360	1330	4500	144	9460	92	-
	mineral soil	2040	1500	1450	5710	151	13200	92	43
Sb	mineral soil	17	7	7	27	2	663	92	1
Zn	litter layer	1250	1200	1100	2670	273	3250	92	-
	mineral soil	912	820	773	2030	176	4190	92	95

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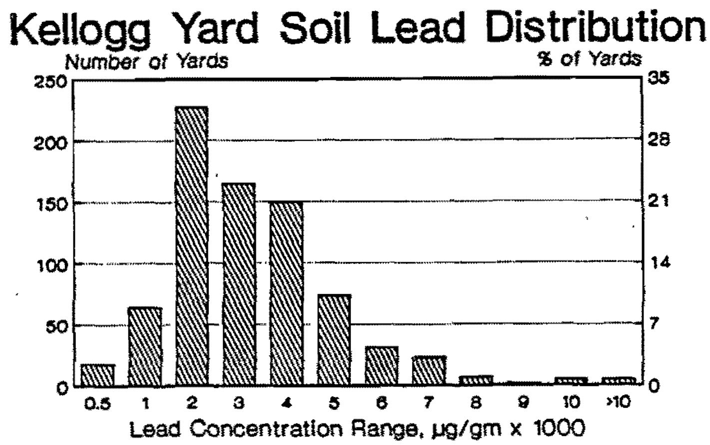
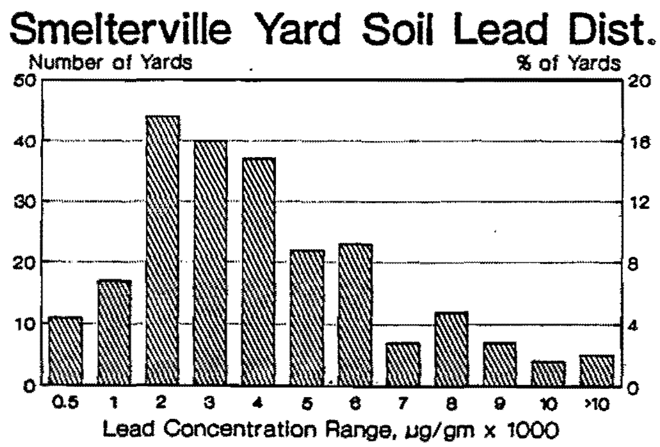
Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, $\mu g/gm$, dry wt. ($\mu g/gm$)							
As	litter layer	26	23	24	45	11	94	50	-
	mineral soil	28	25	26	50	11	81	50	< 10
Cd	litter layer	19	19	17	36	4	38	50	-
	mineral soil	12	11	10	29	1	30	50	0.8
Cu	mineral soil	62	51	51	140	16	238	50	28
Hg	mineral soil	2	1	1	4	0.2	7	50	0.1
Pb	litter layer	1250	1150	1040	3050	127	3580	50	-
	mineral soil	1090	810	808	3220	53	3480	50	43
Sb	mineral soil	7	5	5	16	2	32	50	1
Zn	litter layer	1510	1140	1150	4040	179	4820	50	-
	mineral soil	1060	840	771	3090	107	4050	50	95

FIGURE 2.1

Frequency Distribution of Soil Lead Levels by Town for Residential Yard Soils

Concentrations represent range between listed value and previous value.





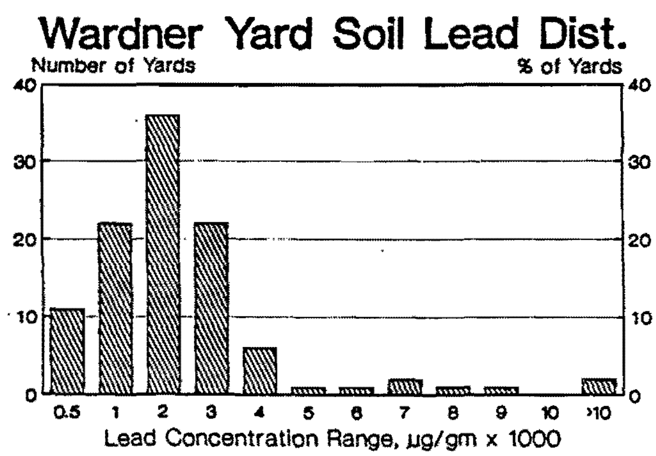
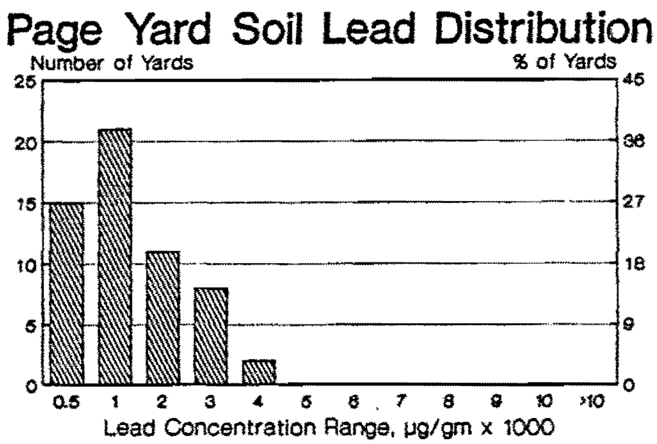
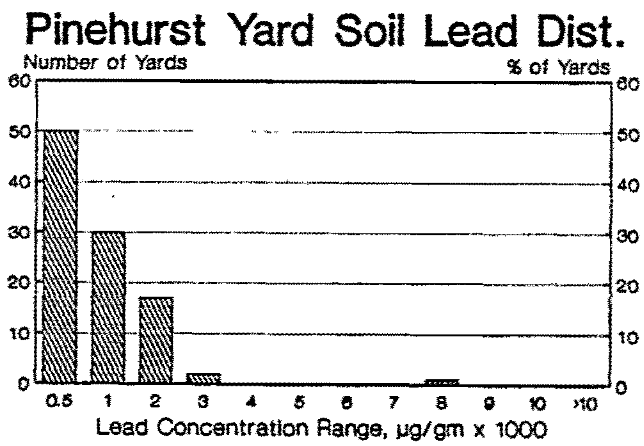


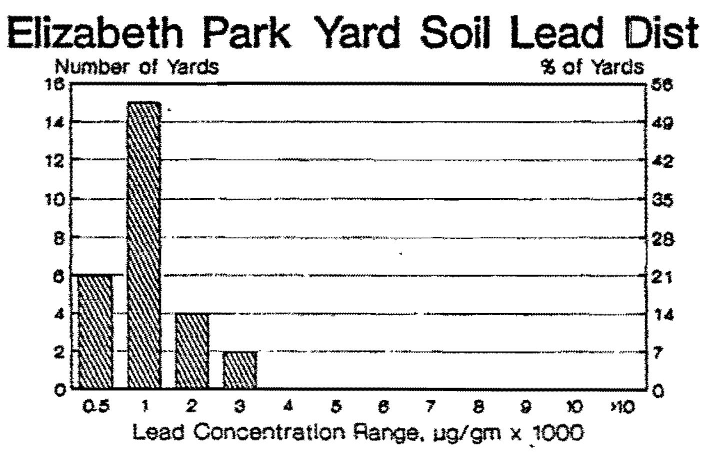
FIGURE 2.1 (Continued)

Frequency Distribution of Soil Lead Levels by Town for Residential Yard Soils

Concentrations represent range between listed value and previous value.







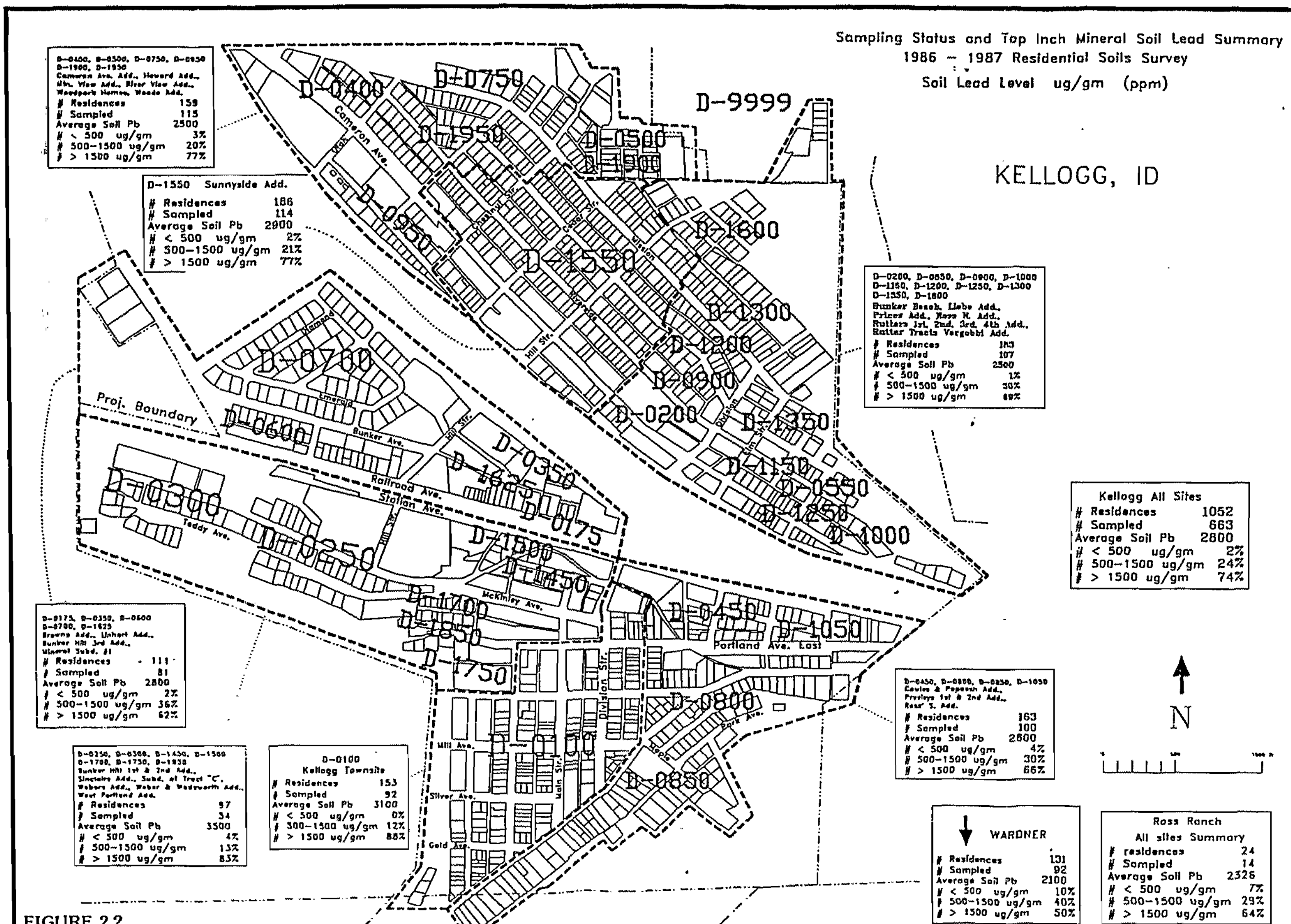


FIGURE 2.2

Summary of Soil Lead Levels by Neighborhood - Kellogg
BUNKER HILL RI/FS

TerraGraphics
ENVIRONMENTAL ENGINEERING

121 South Jackson Street
Moscow, Idaho 83843

File Name KELLPBLV
Drawn by
Approved by

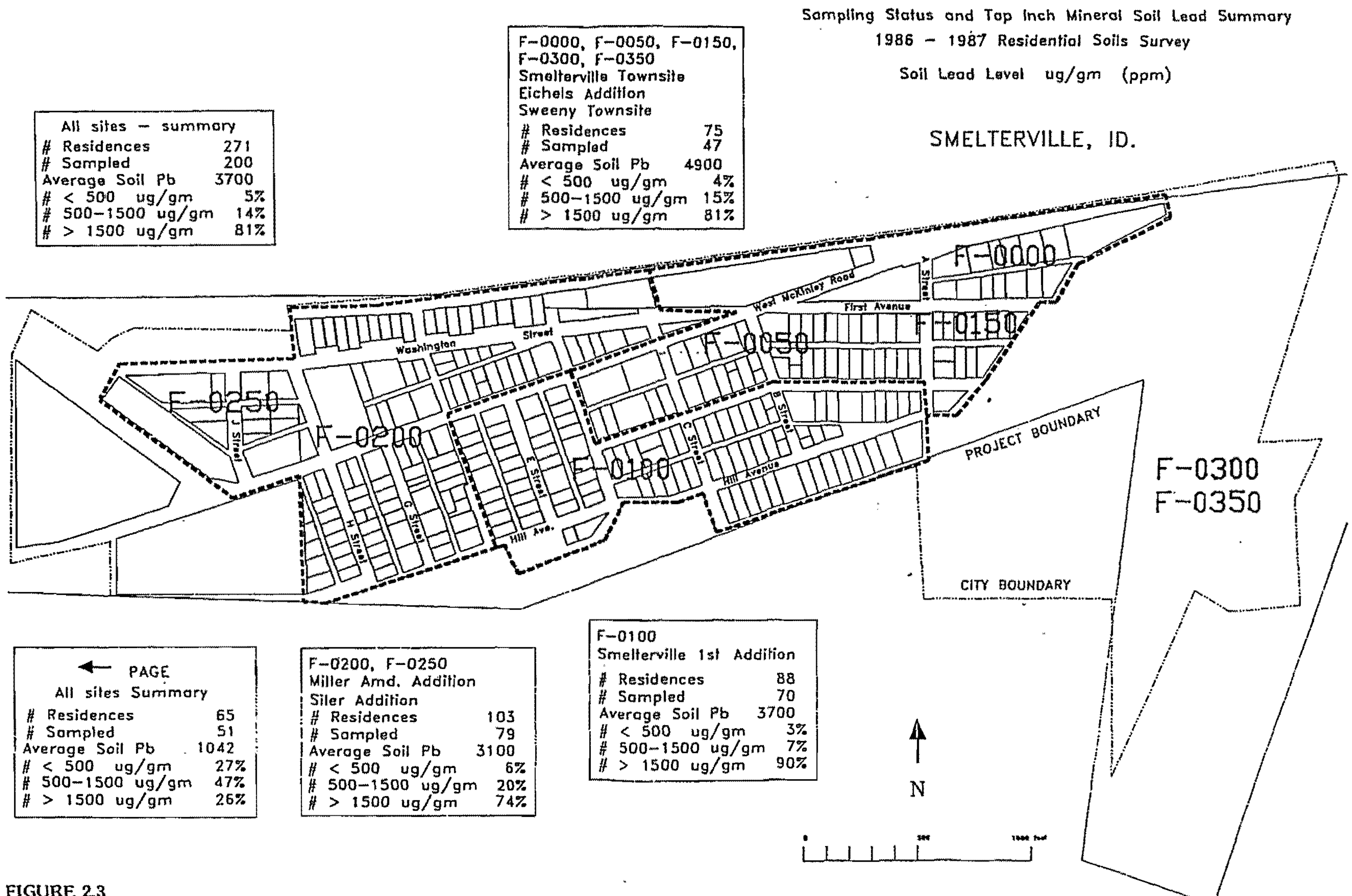


FIGURE 2.3

Summary of Soil Lead Levels by Neighborhood – Smelterville
BUNKER HILL RI/FS

TerraGraphics
ENVIRONMENTAL ENGINEERING
121 South Jackson Street
Moscow, Idaho 83843

File Name SMLTPBLV __/__/__
Drawn by ________ __/__/__
Approved by ________ __/__/__

Table 2.5

Residential Yard Sampling Status and Lead Contamination Summary by Town (Phase I RI)

Kellogg*

# residences	1076
# sampled	677
Avg Soil Pb(μg/gm)	2800
% < 500 μg/gm	2%
% 500-1000 μg/gm	9%
% > 1000 μg/gm	89%

Wardner

# residences	131
# sampled	92
Avg Soil Pb(μg/gm)	2100
% < 500 μg/gm	10%
% 500-1000 μg/gm	21%
% >1000 μg/gm	69%

Smelterville

# residences	271
# sampled	200
Avg Soil Pb(μg/gm)	3700
% < 500 μg/gm	5%
% 500-1000 μg/gm	7%
% > 1000 μg/gm	88%

Page

# residences	65
# sampled	51
Avg Soil Pb(μg/gm)	1042
% < 500 μg/gm	27%
% 500-1000 μg/gm	36%
% > 1000 μg/gm	37%

All Sites - Combined

# residences	1543
# sampled	1020
Avg Soil Pb(μg/gm)	2800
% < 500 μg/gm	5%
% 500-1000 μg/gm	11%
% > 1000 μg/gm	84%

* Includes Ross Ranch.

were candidates for remediation (>1,500 μg/gm Pb). Similar results can be obtained for Page and Wardner or specific neighborhoods in Kellogg and Smelterville from Figures 2.2 and 2.3.

2.1.2.2 1989-90 Residential Soil Removal

Additional residential properties were sampled in 1988-90 as part of emergency removal activities accomplished in the summers of 1989 and 1990. Eighty-one yards and two apartment complexes were remediated in 1989 as part of a program to reduce exposures to young children and pregnant women in the Phase I communities. Residences were selected for remediation based on the combination of the residence housing a pregnant woman or child under three years of age and having an excessive soil lead level. The program was continued in 1990 and extended to homes with children under nine years of age. An estimated 130 additional homes have been remediated in the summer of 1990. Removals have consisted of a one-foot excavation and removal of yard soils, replacement with clean top soil, sodding, and replacement of the yard features to original condition. Garden locations were excavated to depths of 18 to 24 inches and then replaced with a clean layer of top soil.

Approximately 15% of these homes were not surveyed in the 1986-87 effort and samples were obtained as part of the removal efforts. These results were not included in Tables 2.4 and 2.5 or Figures 2.2 and 2.3 because of differences in sampling methodology and reporting of results. Table 2.6 summarizes the removal effort by town for 1989-90.

2.1.2.3 Pinehurst and Elizabeth Park

The City of Pinehurst and the unincorporated residential area of Elizabeth Park were not included in the original 1986-87 Residential Soil Survey. Previous soil and blood lead surveys had indicated that these areas were at substantially lower risk to excess absorption than those in the Phase I communities. Residential soils in Pinehurst and Elizabeth Park were sampled in 1989.

Table 2.6

Summary of Properties Remediated in 1989-90 Removals

	1989		1990	
Town	# of Properties Remediated	Range of Pb Levels in Soils Replaced	# of Homes Remediated	Range of Pb Levels in Soil Replaced
Kellogg	56	454-10400 μg/gm	98	500-24500 μg/gm
Smelterville	17	356-8250 μg/gm	21	500-12800 μg/gm
Page	3	1500-1640 μg/gm	3	500-1510 μg/gm
Wardner	5	587-876 μg/gm	16	500-22700 μg/gm

These communities were scheduled for blood lead screenings in 1990 and additional environmental media data were collected beginning in 1989 (CH2M HILL, 1990d). Residential soil samples were collected from 100 homes in Pinehurst and 27 homes in Elizabeth Park. Property tax records were also obtained and these areas are being added to the site property parcel tracking system. Table 2.7 shows metals results for soils and litters in these two communities.

2.1.2.4 Mercury and Organic Survey

Limited soil sampling was conducted during 1989 in Smelterville, Kellogg, Wardner, Page, Pinehurst, and Elizabeth Park to support analyses for extractable organic compounds, chlorinated pesticides, PCBs, and mercury. Appendix A2.2 presents summary statistics for the parameters detected by area. Most organic analytes were not detected. However, occasional detections are noted for phthalate esters (plasticizer compounds), some polynuclear aromatic hydrocarbons (i.e., naphthalene, phenanthrene, fluoranthene, pyrene, benzo(b) fluoranthene and benzo(a)pyrene as constituents of fossil fuels and their combustion products), and polychlorinated biphenyls (PCBs as components of dielectric fluids). Chlorinated pesticides were detected in several samples in each town. For those pesticides observed, the frequencies of detection in various zones range from a low of 14% for aldrin, lindane, and heptachlor to a high of 100% for DDT isomers and metabolites, chlordane, and heptachlor epoxide. Greatest concentrations and frequencies of detection for pesticides in soils were found in Smelterville, Kellogg, and Wardner with significantly lower levels in Page. Risk assessment for pesticide exposures in remaining residential soils is not presented in this document pending additional sampling and analysis.

Table 2.7

SUMMARY OF 1989 RESIDENTIAL SOIL METAL CONTAMINATION LEVELS - PHASE II COMMUNITIES

ELIZABETH PARK

Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, µg/gm, dry wt. (µg/gm)							
As	mineral soil	29	22	23	94	9	131	27	< 10
Cd	mineral soil	10	11	9	16	2	18	27	0.8
Cu	mineral soil	47	41	43	81	24	116	27	28
Hg	mineral soil	1	1	1	2	0.1	3	27	0.1
Pb	mineral soil	799	734	679	2060	97	2090	27	43
Sb	mineral soil	10	7	9	21	5	32	27	1
Zn	mineral soil	440	453	406	680	142	704	27	95

PINEHURST

Metal		Arith. Mean	Median	Geom. Mean	95%ile	Min.	Max.	N	Background Mean
		Concentration, µg/gm, dry wt. (µg/gm)							
As	mineral soil	30	21	23	73	7	123	100	< 10
Cd	mineral soil	6	6	5	13	1	37	100	0.8
Cu	mineral soil	43	40	39	85	17	167	100	28
Hg	mineral soil	0.5	0.4	0.4	1	0.1	4	100	0.1
Pb	mineral soil	683	501	463	1260	63	7990	100	43
Sb	mineral soil	9	7	8	19	5	41	100	1
Zn	mineral soil	474	394	389	1060	99	2300	100	95

2.1.3 Commercial Properties and Roadsides

Phase II RI efforts in the summer of 1989 also included sampling a number of commercial properties and roadsides within the Populated Areas. The purpose of this sampling effort was to ascertain the extent of contamination on commercial lots and along various roads, and to evaluate the potential for contaminant transport and recontamination from these areas (CH2M HILL, 1990d).

All soil surfaces around commercial establishments within the project area where a confidentiality agreement could be obtained were surveyed. In total, 89 properties were sampled. Where possible, three samples were collected from each property. Those included 0- to 1-inch composite of mineral soil from two sub-sites, a 0- to 6-inch composite from one of the two sub-sites and a 6- to 12-inch composite taken from the same location as the 0- to 6-inch sample. The first two samples were obtained at all sites. In some cases, the third sample was not obtained because of auger refusal. Using these techniques, 283 samples were obtained, including quality assurance/quality control (QA/QC) samples.

These samples were analyzed by a portable X-ray Fluorescence (XRF) technique documented in CH2M HILL, 1990d. Twenty-nine samples were split and analyzed by EPA-CLP methods at the laboratory. Tables 2.8a, 2.8b, and 2.8c summarize the CLP laboratory results for commercial properties.

Only a small number of samples (29) were analyzed by CLP techniques, and not all samples from differing depths at the same location were analyzed. As a result, the values indicated in Tables 2.8a, 2.8b, 2.8c can only provide a qualitative sense of contaminant levels on commercial properties in the three cities. Lead levels in Smelterville commercial areas varied from 1,100 to 18,000 μg/gm, in Kellogg from 384 to 25,100 μg/gm, and in Pinehurst from 234 to 1,350 μg/gm. Cadmium levels were from 10 to 149 μg/gm in Smelterville, 3 to 107 μg/gm in Kellogg, and 3 to 19 μg/gm in Pinehurst.

Table 2.8a
Commercial Property Soil Metals Summary
Smelterville

Concentration (µg/gm, dry wt.)

Element	Sample Description	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	N	Background Mean[a]
As	Mineral soil, 0- to 6-inch depth	114.4	--	96.40	--	52.8	176	2	<10
	Mineral soil, 6- to 12-inch depth	--	--	--	--	178	178	1	
Cd	Mineral soil, 0- to 6-inch depth	79.55	--	38.79	--	10.1	149	2	0.8
	Mineral soil, 6- to 12-inch depth	--	--	--	--	58	58	1	
Cr	Mineral soil	--	--	--	--	--	--	0	35.0
Cu	Mineral soil, 0- to 6-inch depth	347	--	245	--	101	593	2	28.0
	Mineral soil, 6- to 12-inch depth	--	--	--	--	454	454	1	
Hg	Mineral soil, 0- to 6-inch depth	4.96	--	2.00	--	0.42	9.5	2	0.1
	Mineral soil, 6- to 12-inch depth	--	--	--	--	9.2	9.2	1	
Mn	Mineral soil	--	--	--	--	--	--	0	1333
Ni	Mineral soil	--	--	--	--	--	--	0	23
Pb	Mineral soil, 0- to 6-inch depth	6055	--	3494	--	1110	11000	2	43.0
	Mineral soil, 6- to 12-inch depth	--	--	--	--	18000	18000	1	
Sb	Mineral soil, 0- to 6-inch depth	36.9	--	24	--	8.8	65.0	2	1.1
	Mineral soil, 6- to 12-inch depth	--	--	--	--	78.5	78.5	1	
Se	Mineral soil	--	--	--	--	--	--	0	--
Zn	Mineral soil, 0- to 6-inch depth	3985	--	3024	--	1390	6580	2	95.0
	Mineral soil, 6- to 12-inch depth	--	--	--	--	9490	9490	1	

Note: All statistical calculations were conducted using detection limits as actual values.

(a) Gott and Cathrall, 1980.

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Table 2.8b
Commercial Property Soil Metals Summary
Kellogg

Concentration (µg/gm, dry wt.)

Element	Sample Description	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	N	Background Mean[(a)]
As	Mineral soil, 0- to 1-inch depth	119	69.6	99.2	--	61.7	227	3	<10
	Mineral soil, 0- to 6-inch depth	72	42.1	47.4	--	14	172	6	
	Mineral soil, 6- to 12-inch depth	48	45.8	43.3	--	20	79	5	
Cd	Mineral soil, 0- to 1-inch depth	55.2	57.0	49.5	--	25.7	82.9	3	0.8
	Mineral soil, 0- to 6-inch depth	21.6	8.4	11.9	--	3.1	77.1	6	
	Mineral soil, 6- to 12-inch depth	31.1	12.2	17.0	--	6.2	107	5	
Cr	Mineral soil	--	--	--	--	--	--	0	35.0
Cu	Mineral soil, 0- to 1-inch depth	340	172	254	--	133	716	3	28.0
	Mineral soil, 0- to 6-inch depth	102	79	70	--	26	289	6	
	Mineral soil, 6- to 12-inch depth	206	213	137	--	40	470	5	
Hg	Mineral soil, 0- to 1-inch depth	4.6	5.4	3.9	--	1.6	6.7	3	0.1
	Mineral soil, 0- to 6-inch depth	1.5	0.6	0.7	--	0.1	5.7	6	
	Mineral soil, 6- to 12-inch depth	7.0	1.3	2.6	--	0.4	20.3	5	
Mn	Mineral soil	--	--	--	--	--	--	0	1333
Ni	Mineral soil	--	--	--	--	--	--	0	23
Pb	Mineral soil, 0- to 1-inch depth	6146.7	4710	5666.6	--	3950	9780	3	43.0
	Mineral soil, 0- to 6-inch depth	5564.7	1247	1735.8	--	384.0	25100	6	
	Mineral soil, 6- to 12-inch depth	6768	6510	3474	--	590	18700	5	
Sb	Mineral soil, 0- to 1-inch depth	47.4	35.2	41.2	--	<24.0	82.9	3	1.1
	Mineral soil, 0- to 6-inch depth	20.9	9.7	12.5	--	<5.2	74.1	6	
	Mineral soil, 6- to 12-inch depth	32.7	29.3	23.5	--	<6.1	69.6	5	
Se	Mineral soil	--	--	--	--	--	--	0	--
Zn	Mineral soil, 0- to 1-inch depth	3876.7	3210	3189.3	--	1450	6970	3	95.0
	Mineral soil, 0- to 6-inch depth	2387.0	533	868.5	--	211.0	9100	6	
	Mineral soil, 6 to 12-inch depth	1874	1870	1371	--	348	3240	5	

Note: All statistical calculations were conducted using detection limits as actual values.

Source:

(a) Gott and Cathrall, 1980.

Table 2.8c
Commercial Property Soil Metals Summary
Pinehurst

Concentration (μg/gm, dry wt.)

Element	Sample Description	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	N	Background Mean[a]
As	Mineral soil, 0- to 1-inch depth	56.2	56.2	53.8	--	40.1	72.3	2	<10
	Mineral soil, 0- to 6-inch depth	26.4	22.2	41.8	--	9.2	59.5	5	
Cd	Mineral soil, 0- to 1-inch depth	11.9	11.9	11.8	--	11.2	12.5	2	0.8
	Mineral soil, 0- to 6-inch depth	7.4	6.2	8.6	--	2.8	19.1	5	
Cr	Mineral soil	--	--	--	--	--	--	0	35.0
Cu	Mineral soil, 0- to 1-inch depth	87.4	87.4	80.6	--	53.7	121.0	2	28.0
	Mineral soil, 0- to 6-inch depth	70.9	34.4	98.1	--	23.0	253.0	5	
Hg	Mineral soil, 0- to 1-inch depth	0.5	0.5	0.5	--	0.3	0.8	2	0.1
	Mineral soil, 0- to 6-inch depth	1.4	0.27	0.3	--	0.1	7.2	5	
Mn	Mineral soil	--	--	--	--	--	--	0	1333
Ni	Mineral soil	--	--	--	--	--	--	0	23
Pb	Mineral soil, 0- to 1-inch depth	1250	1250	1246	--	1150	1350	2	43.0
	Mineral soil, 0- to 6-inch depth	386.7	328	1139.5	--	234.0	809.0	5	
Sb	Mineral soil, 0- to 1-inch depth	15.7	15.7	15.6	--	14.3	17.1	2	1.1
	Mineral soil, 0- to 6-inch depth	9.1	5.8	11.1	--	<5.2	25.0	5	
Se	Mineral soil	--	--	--	--	--	--	0	--
Zn	Mineral soil, 0- to 1-inch depth	1462	1462	1267	--	733	2190	2	95.0
	Mineral soil, 0- to 6-inch depth	765.2	308	1694.5	--	239.0	2490.0	5	

Note: All statistical calculations were conducted using detection limits as actual values.

Source:

(a) Gott and Cathrall, 1980.

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Arsenic levels ranged from 53 to 178 μg/gm in Smelterville, 14 to 227 μg/gm in Kellogg, and 9 to 72 μg/gm in Pinehurst. These concentrations are all consistent with metals levels observed in residential area soils.

Surface samples (top-inch) from curbless road shoulders along streets in different portions of the project area were also collected during the Phase II RI effort. The first sample site on a selected road was 0.1 mile from where the road entered or began in the project area. Subsequent sampling sites were every 0.2 mile thereafter until the road ended or exited the project area. At each sample site, two samples were taken--one from each side of the road. If a curb was present on one side of the road, a single sample was taken. This resulted in 129 sites being sampled. Including QA/QC samples, a total of 281 samples were analyzed by XRF and 27 samples were split and analyzed by CLP techniques.

Top-inch surface samples were also collected from 20 sites along the railroad right-of-way. One sample was collected in Elizabeth Park, eight in Kellogg and eleven in Smelterville. In Kellogg and Smelterville, sample sites were 0.2 mile apart. Samples were collected from the cardinal points (points located 90 degrees apart) of two 1-meter arcs, with an arc located on each side of the track. All of the cardinal point samples from both arcs (eight sub-samples) were composited. These samples were analyzed by XRF, and the samples with the two highest lead concentrations, the two lowest, and the two median lead concentrations were split for CLP analysis. Including QA/QC samples, a total of 25 samples were analyzed by XRF, with nine samples being sent to the CLP.

Table 2.9 summarizes CLP Laboratory results for road shoulders, railroad right-of-ways, and street sweepings.

Table 2.9

SUMMARY ROAD SHOULDERS AND RAILROAD RIGHT-OF-WAY SAMPLE SURVEY

	Sb µg/gm	As µg/gm	Cd µg/gm	Cu µg/gm	Pb µg/gm	Hg µg/gm	Zn µg/gm
Road Shoulder							
Smelterville	9.4	19.4	3	33.9	249	1.3	220
Smelterville	41.7	115	14.2	186	6970	3.8	2590
Smelterville	32.7	50.8	26.9	499	2410	0.06	10100
Smelterville	40.5	77.7	61.5	274	4970	0.08	4770
Smelterville	46.2	267	312	1950	10200	2.4	23600
Smelterville	534	810	487	2820	60100	26.2	20200
Kellogg Sunnyside	8.6	36.2	16.2	106	1590	0.52	1560
Kellogg Sunnyside	19.8	103	22.6	297	2280	0.35	5360
Kellogg Old Town	34.8	110	31.1	214	7430	3.8	2710
Kellogg Old Town	5.9	31.8	28.7	161	1990	0.94	3270
Kellogg Old Town	22.6	102	26	305	4070	0.79	7210
Wardner	5.2	44.4	12.2	352	1300	0.16	8560
Pinehurst	23.2	87.1	11.2	131	1010	0.24	2220
Pinehurst	9.4	19.4	9	84.9	725	0.3	1520
Pinehurst	13.6	47.1	10.5	290	1020	0.11	6740
Pinehurst	18.2	85.9	24.5	475	1580	0.06	9980
Pinehurst	5.2	41	9	814	425	0.38	18700
Pinehurst	12.4	149	12	570	735	0.46	12300
Pinehurst	36.7	85.1	11.2	596	2110	0.46	10600
Pinehurst	21.7	96.2	36.2	700	3560	0.6	10900
Page	5.2	23.2	9.2	203	480	0.14	4390
Page	5.2	24.9	11.8	487	595	0.16	11600
Page	5.2	47.7	65.4	842	1380	1.3	22500
Elizabeth Park	7	15.1	5.2	99.9	329	0.28	2200
Elizabeth Park	9.5	36.4	18.9	631	1060	0.14	14700
Railroad Right-of-Way							
Smelterville	60.9	185	41.8	407	17600	15.4	4510
Smelterville	58.4	205	43	360	13400	5.9	4110
Kellogg Old Town	18.9	75.6	33.8	205	8530	2.3	3470
Kellogg Old Town	99.5	396	344	1080	44900	8.3	43500
Kellogg Old Town	38.2	249	27.9	233	8390	4.9	3170
Elizabeth Park	7.3	44.4	10.7	75.1	2710	1.6	1060
Street Sweeper Dust							
Smelterville	8.4	47.2	16.8	135	1560	1.8	2910
Smelterville	31.3	148	7.7	475	2230	0.93	10800
Smelterville	31.4	70.1	21.5	437	1930	0.7	10700

The concentration of metals in roadside samples shows considerable variation, both geographically and within towns. Samples from Smelterville ranged from 249 to 60,100 µg/gm Pb, 3 to 487 µg/gm Cd, and 19 to 810 µg/gm As. Samples from the Sunnyside Area of Kellogg averaged 1,935 µg/gm Pb, 19 µg/gm Cd, and 71 µg/gm As.

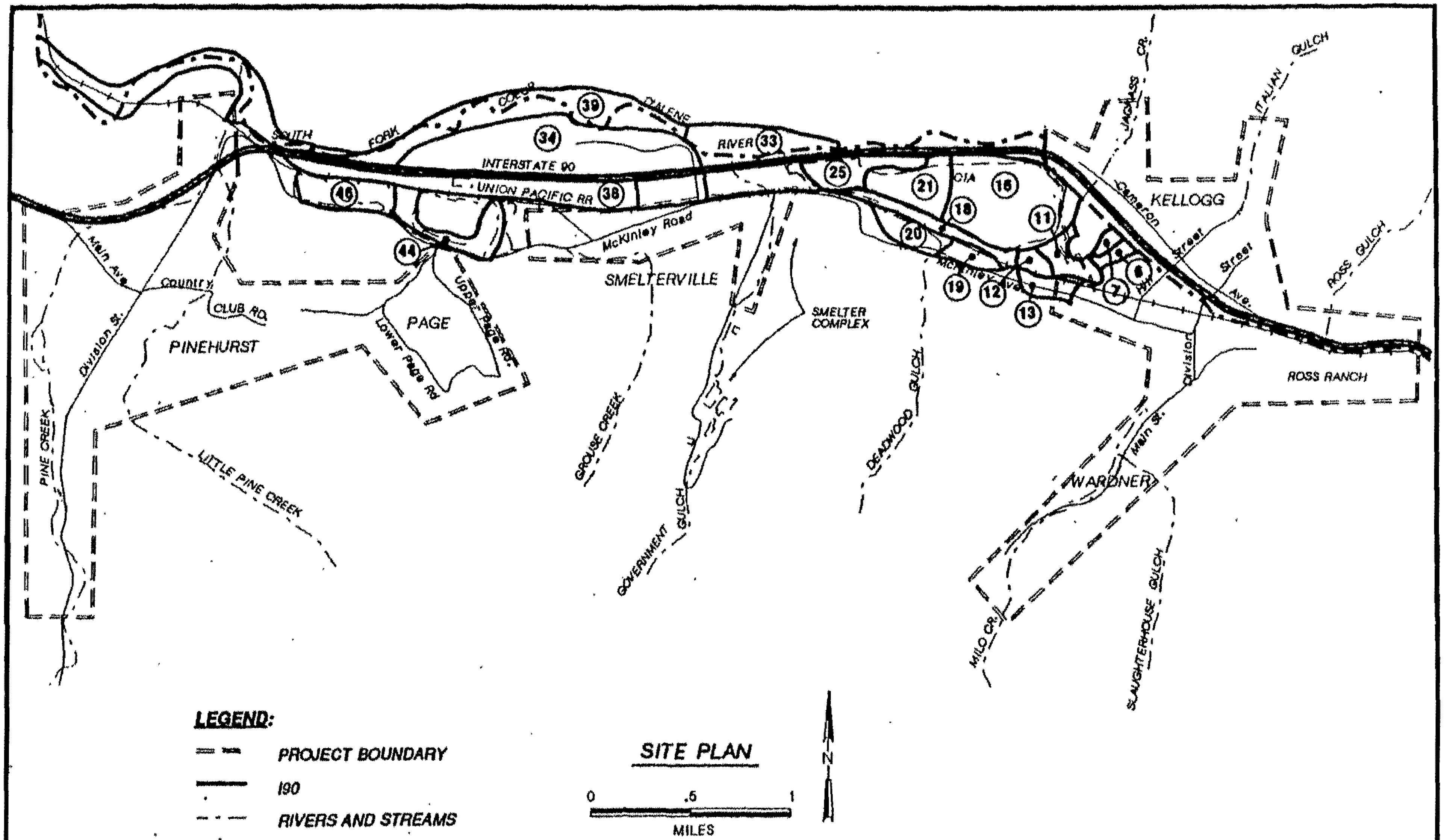
Old Town Area samples averaged 4,497 $\mu g/gm$ Pb, 28.6 $\mu g/gm$ Cd, and 81 $\mu g/gm$ As. Wardner and Pinehurst area samples were notably lower averaging 1,385 $\mu g/gm$ Pb, 15 $\mu g/gm$ Cd, and 73 $\mu g/gm$ As. Samples of street-sweeper dust showed lead contents from 1,560 to 2,230 $\mu g/gm$ and zinc levels exceeding 10,000 $\mu g/gm$ (1%). The latter concentrations are likely indicative of slag use on local roadways.

Railroad right-of-way samples showed high metal concentrations throughout the site. Concentrations ranged from 2,710 to 44,900 $\mu g/gm$ Pb, from 44 to 396 $\mu g/gm$ As, 1,060 to 43,500 $\mu g/gm$ Zn, and 11 to 344 $\mu g/gm$ Cd. These results are indicative of spilled ores and concentrates and could represent both a direct contact and contaminant migration hazard.

2.1.4 Fugitive Dust Sources

The migration and transport of contaminated solids from the smelter facility, industrial complex and other fugitive dust sources are a major concern in both the Populated and Non-populated Areas of the site. Windblown dusts are potentially significant contributors to contaminant concentrations in human receptor media in the Populated Areas and have been identified as a major source of public complaint. Many of the identified fugitive dust sources are barren soils and impounded wastes and storage piles that can result in significant amounts of re-entrained dusts.

Eighteen major barren areas identified as having a potentially significant impact on the residential areas were sampled during remedial investigations in 1986. Table 2.10 identifies the areas sampled, the respective size of each area, the number of samples collected, summary statistics for lead content in the minus 200 mesh portion of the sample, and the average percentage (by weight) that passed the 200-mesh sieve. Complete metal results can be found in CH2M HILL, 1990b and Appendix A2.3. No sample exhibited less than detectable levels of antimony, arsenic, cadmium, copper, lead and zinc. Locations of the fugitive dust source areas are provided in Figure 2.4.



NOTE:
DESCRIPTIONS FOR SOURCE AREA IDENTIFICATION NUMBERS ARE PRESENTED IN TABLE 2.10.

Figure 2.4
POTENTIAL SOURCE IDENTIFICATION MAP FOR WINDBLOWN DUSTS

BOI24 X1.01

Table 2.10

FUGITIVE DUST SOURCE AREAS

Map I.D. Number	Site Name	# of Samples	Area (Acres)	Lead Conc (μg/gm) Min	Mean	Max	% of Sample < 200 Mesh
6	Vacant lot west of Mineral Subdivision	8	9	13400	19900	26600	15%
7	Undeveloped area near the Junior High School	4	6	1160	1810	2500	26%
11	Area near Shoshone Apartments	8	27	30900	49100	68400	28%
12	Water treatment plant	4	6	40000	43400	48700	22%
13	Parking lot west of Concentrator Building	4	6	212000	232000	252000	30%
16	Central Impoundment Area (North Beaches)	20	150	117	5530	25300	51%
18	Bunker Creek Corridor	12	33	10300	19300	42400	31%
19	Old homesite area	8	9	6560	21100	47500	47%
20	Old Gypsum Pond	8	29	8050	62000	85800	18%
21	New Gypsum Pond	12	61	78	2160	10900	30%
25	Slag pile	12	26	1370	10700	18200	15%
33	Outdoor theater	8	83	2950	9190	15900	18%
34	Airport	24	232	11100	15500	28200	29%
38	Smelterville Corridor	16	127	11600	19800	32700	33%
39	River Channel Flats	12	70	3970	5340	6310	6%
44	Page Ponds	12	36	2560	4350	6550	68%
46	Page Swamp	4	44	3850	4710	6000	57%
	Smelterville	--	--	9690	15100	25400	14%

Highest metal concentrations among fugitive dust sources were found adjacent to the concentrator building, with the lead concentration averaging about 230,000 μg/gm (23%), and arsenic and cadmium levels each at approximately 10,000 μg/gm (1%). Dust content for this sample was high with 30% of the solids passing a 200-mesh sieve. The surrounding areas (11 and 12) also have relatively high metal contaminant levels that may be related to emissions from the concentrator area. Barren areas near Shoshone Apartments (Area 11) and the Water Treatment Plant (Area 12) exhibit approximately 49,000 μg/gm (4.9%) and 43,000 μg/gm (4.3%) lead in surface dust, respectively. The arithmetic mean lead concentration for all fugitive dust source areas is 28,400 μg/gm (2.8%). Source areas near the smelter complex and throughout the river flood plain routinely exhibited levels in excess of 2% lead. Percent of sample solids to pass 200-mesh ranged from 6 to 68%, averaging 30% for all samples.

The metals concentrations and silt content levels exhibited are extremely high. Consequently, these sources are a major health concern for the area. They represent both a direct contact hazard to humans accessing the sites and are, likely, primary sources of continuing contamination to soils and household dust media in the Populated Areas. Emission rates and potential impact estimates have been developed for these sources and are presented in Section 4 of this report as contaminant fate and transport issues.

2.2 Results of Air Investigations

2.2.1 Air Quality Monitoring

2.2.1.1 NAAQS Monitoring

Ambient air monitoring for Total Suspended Particulates (TSP) and lead have been conducted at the Bunker Hill Site pursuant to National Ambient Air Quality Standards (NAAQS) since 1971. These data have been summarized in JEG et al., 1989. Table 2.11 shows historical TSP and lead results for the site. Figure 2.5 shows historical lead concentrations for select stations. Ambient lead loadings were significantly higher during smelter operations years and particularly in 1973-74 when smelter air pollution control was defective. Figure 2.6 shows monitor locations for the several studies discussed in this section.

Since smelter closure, ambient TSP and lead levels have generally been within primary NAAQS requirements. TSP values ranged from 30 $\mu g/m^3$ to 70 $\mu g/m^3$ on an annual basis with daily values ranging to 900 $\mu g/m^3$. Atmospheric lead concentrations have ranged from 0.1 $\mu g/m^3$ to 0.5 $\mu g/m^3$ on a quarterly basis with daily observations as high as 2.8 $\mu g/m^3$. Particulate levels vary on a seasonal basis with the highest levels observed in July through October. Secondary peaks are noted in late winter or early spring,

Table 2.11 (Page 1 of 5)
Air Concentrations of Lead and TSP
($\mu g/m^3$) 1971-1988[(a)]

		Lead (TSP)						
		Quarterly Average						
	Year	1	2	3	4	Annual Average[(d)]	Highest 24-hour Average	Number of Observations
Kellogg Medical Clinic	1971	6.1 (151)	5.1 (108)	5.5 (122)	16.0 (102)	8.2 (118)	41.8 (287)	31(34)
	1972	5.6 (125)	7.9 (112)	9.3 (147)	12.4 (165)	9.6 (139)	23.1 (362)	38 (39)
	1973	16.2 (147)	9.7 (148)	15.0 (192)	19.3 (122)	13.2[(b)] (151)	34.9 (4.51)	35 (78)
	1974	1.9 (123)	13.0 (123)	12.2 (145)	10.4 (122)	11.9[(c)] (128)	42.5 (503)	122 (140)
	1975	7.1 (96)	5.3 (82)	6.0 (96)	11.2 (94)	7.4 (93)	53.1 (244)	144 (131)
	1976	7.1 (96)	4.2 (107)	9.4 (108)	9.4 (115)	7.5 (274)	25.4 (716)	107 (107)
	1977	9.6 (116)	6.6 (91)	4.2 (74)	6.7 (68)	6.8 (88)	22.5 (211)	91 (91)
	1978	5.9 (80)	2.4 (71)	4.2 (79)	9.2 (105)	5.4 (84)	36.5 (343)	102 (103)
	1979	8.3 (92)	4.9 (98)	4.8 (96)	5.4 (96)	5.9 (96)	29.0 (364)	106 (107)
	1980	6.8 (101)	3.3 (603)	4.6 (124)	8.7 (117)	5.9 (235)	27.1 (10,380)	91 (101)
	1981	6.7 (106)	2.4 (60)	2.2 (114)	5.0 (83)	4.1 (91)	16.1 (446)	56 (61)
	1982	0.37 (64)	0.39 (55)	0.18 (47)	0.16 (41)	0.28 (51)	2.1 (166)	61 (61)
	1983	0.24 (101)	0.21 (114)	0.12 (71)	0.18 (88)	0.19 (54)	0.68 (163)	57 (57)
	1984	0.16 (117)	0.12 (86)	0.09 (64)	0.12 (82)	0.12 (47)	0.41 (142)	57 (57)
	1985	0.17 (135)	0.08 (55)	0.13 (139)	0.15 (80)	0.13 (57)	0.56 (226)	61 (61)
	1986	0.16 (151)	0.15 (83)	0.13 (670)	0.30 (81)	0.19 (55)	1.12 (229)	59 (50)
	1987	0.23 (85)	0.12 (81)	0.13 (57)	0.18 (96)	0.17 (51)	0.67 (110)	55 (600)
	1988	0.11 (104)	0.07 (70)	0.14	0.10	0.11 (45)	1.01 (120)	70 (70)

Table 2.11 (Page 2 of 5)
Air Concentrations of Lead and TSP
($\mu g/m^3$) 1971-1988[a]

		Lead (TSP)						
		Quarterly Average						
	Year	1	2	3	4	Annual Average[d]	Highest 24-hour Average	Number of Observations
Silver King School	1974	--	22.9 (175)	32.0 (173)	19.0 (155)	25.5 (172)	125.7 (631)	55 (56)
	1975	15.5 (126)	12.4 (97)	17.1 (122)	18.8 (110)	16.0 (113)	61.0 (453)	144 (132)
	1976	12.7 (126)	11.5 (113)	18.5 (128)	16.7 (136)	14.9 (125)	82.1 (718)	110 (110)
	1977	14.9 (128)	15.8 (99)	12.1 (84)	13.0 (87)	14.0 (100)	63.0 (291)	95 (95)
	1978	10.6 (78)	6.2 (64)	7.0 (87)	19.0 (167)	10.7 (108)	138.4 (1,408)	106 (106)
	1979	13.5 (100)	8.0 (91)	11.1 (114)	10.4 (101)	10.8 (101)	63.9 (427)	106 (106)
	1980	13.3 (125)	4.1 (58)	9.2 (135)	13.7 (119)	10.2 (177)	98.6 (5,072)	92 (103)
	1981	11.8 (106)	3.7 (58)	6.5 (135)	7.9 (84)	7.5 (96)	32.8 (528)	56 (62)
	1982	1.8 (42)	1.0 (45)	0.51 (44)	0.20 (25)	0.88 (39)	7.7 (118)	59 (59)
	1983	0.27 (59)	0.26 (75)	0.13 (71)	0.13 (56)	0.20 (37)	1.9 (122)	55 (55)
	1984	0.17 (57)	0.10 (70)	0.15 (59)	0.07 (52)	0.12 (33)	0.91 (108)	55 (55)
	1985	0.12 (55)	0.12 (46)	0.16 (140)	0.35 (84)	0.19 (41)	2.8 (266)	62 (62)
	1986	0.18 (51)	0.16 (71)	0.40 (77)	0.45 (56)	0.30 (36)	1.8 (129)	60 (60)
	1987	0.53 (53)	0.19 (66)	--	--	0.36 (39)	1.3 (94)	29 (29)

Table 2.11 (Page 3 of 5)
Air Concentrations of Lead and TSP
($\mu g/m^3$) 1971-1988[(a)]

		Lead (TSP)						
		Quarterly Average						
	Year	1	2	3	4	Annual Average[(d)]	Highest 24-hour Average	Number of Observations
Pinehurst School	1974	--	--	7.7 (175)	4.6 (137)	6.1 (153)	22.3 (507)	65 (65)
	1975	3.3 (88)	1.8 (80)	3.9 (108)	3.2 (91)	3.1 (93)	15.5 (222)	138 (127)
	1976	3.3 (89)	1.3 (83)	3.8 (87)	5.0 (131)	3.4 (96)	19.9 (235)	105 (105)
	1977	4.9 (115)	2.9 (89)	2.3 (77)	4.2 (100)	3.6 (94)	20.9 (371)	85 (86)
	1978	3.0 (84)	10.0 (59)	1.6 (64)	5.1 (107)	2.7 (78)	21.7 (215)	102 (102)
	1979	4.6 (88)	1.7 (78)	3.1 (106)	2.9 (97)	3.1 (92)	22.9 (256)	105 (106)
	1980	2.4 (116)	0.9 (422)	2.2 (121)	3.3 (123)	2.2 (198)	9.6 (7,148)	90 (100)
	1981	1.5 (132)	0.7 (64)	1.0 (113)	1.5 (104)	1.2 (103)	10.2 (413)	56 (61)
	1982	0.29 (203)	0.07 (102)	0.09 (93)	0.17 (72)	0.16 (117)	0.81 (561)	62 (61)
	1983	0.22 (194)	0.09 (84)	0.08 (71)	0.17 (129)	0.14 (80)	0.45 (278)	57 (57)
	1984	0.12 (169)	0.06 (77)	0.08 (75)	0.09 (142)	0.09 (70)	0.28 (196)	56 (56)
	1985	0.15 (206)	0.07 (73)	0.07 (76)	0.11 (147)	0.10 (78)	0.34 (234)	60 (60)
	1986	0.11 (234)	0.09 (64)	0.09 (72)	0.09 (122)	0.10 (80)	0.34 (372)	60 (60)
	1987	0.12 (175)	0.04 (75)	0.08 (66)	0.08	0.08 (77)	0.23 (196)	60 (46)
PM_{10}	1986	--	--	--	--	--	-- (375)	--
PM_{10}	1987	--	--	--	--	-- (67)	-- (189)	--

Table 2.11 (Page 4 of 5)
Air Concentrations of Lead and TSP
($\mu g/m^3$) 1971-1988[a]

	Year	Lead (TSP) Quarterly Average 1	2	3	4	Annual Average[d]	Highest 24-hour Average	Number of Observations
Smelterville City Hall	1971	5.7 (243)	3.5 (153)	7.9 (185)	5.8 (153)	5.7 (126)	14.9 (385)	29 (36)
	1972	13.2 (231)	10.7 (199)	7.0 (218)	14.0 (615)	11.2 (173)	54.5 (1075)	38 (38)
	1973	13.0 (179)	15.8 (308)	20.6 (38.5)	23.8 (265)	16.5 (164)	40.0 (496)	25 (68)
	1974	1.4 (164)	14.5 (357)	16.3 (291)	12.2 (374)	11.1 (152)	50.0 (615)	100 (106)
	1975	10.7 (293)	5.8 (156)	9.4 (165)	10.0 (201)	9.0 (102)	41.2 (309)	144 (133)
	1976	8.3 (333)	6.3 (231)	12.3 (169)	12.3 (19.5)	9.8 (121)	26.9 (451)	108 (108)
	1977	11.6 (221)	9.4 (162)	6.8 (125)	8.7 (142)	9.1 (100)	29.6 (250)	91 (91)
	1978	7.6 (178)	3.8 (135)	4.8 (243)	14.6 (157)	5.4 (86)	30.9 (452)	80 (80)
Kellogg City Hall	1971	8.8 (111)	3.5 (104)	5.7 (109)	12.3 (121)	7.0 (106)	33.8 (222)	45 (51)
	1972	--	--	--	--	-- (183)	--	-- (1)
	1973	--	9.8 (124)	14.5 (148)	20.7 (109)	14.3[e] (129)	102 (481)	72 (77)
	1974	2.8 (141)	13.3 (124)	10.8 (129)	11.2 (125)	11.8[f] (128)	53.9 (501)	109 (114)
	1975	7.9 (92)	5.7 (86)	5.9 (91)	12.0 (89)	7.9 (89)	77.8 (243)	130 (121)
	1976	7.1 (97)	4.1 (96)	8.3 (97)	9.4 (116)	7.2 (101)	32.1 (370)	112 (112)
	1977	10.9 (122)	6.4 (78)	4.6 (68)	6.1 (77)	7.0 (86)	29.6 (205)	84 (88)

Table 2.11 (Page 5 of 5)
Air Concentrations of Lead and TSP
($\mu g/m^3$) 1971-1988[a]

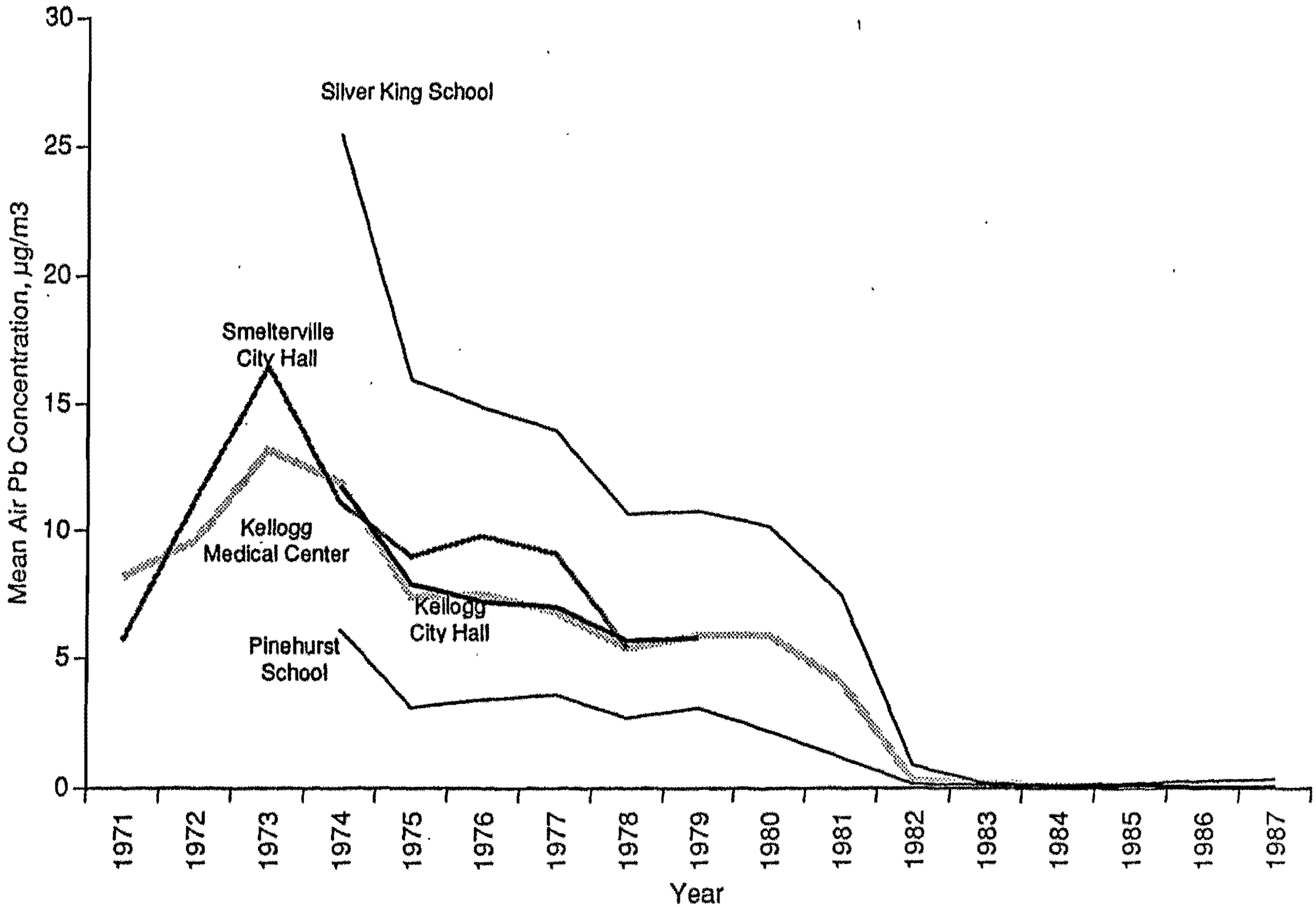
		Lead (TSP)						
		Quarterly Average						
	Year	1	2	3	4	Annual Average[d]	Highest 24-hour Average	Number of Observations
Kellog (continued)	1978	6.2 (84)	2.9 (57)	3.5 (66)	10.3 (110)	5.7 (82)	39.5 (511)	93 (93)
	1979	9.0 (89)	5.1 (97)	4.0 (84)	5.2 (89)	5.8 (90)	40.8 (198)	108 (108)
	1980	6.9 (111)	3.1 (370)	--	--	-- (243)	32.6 (5,084)	44 (55)

(a) Source: EPA, 1989i (EPA Aerometric Information Retrieval System (AIRS) Air Quality Subsystem Quick Look Report).
(b) Assuming a fourth quarter concentration of 19.3 $\mu g/m^3$ (WCC, 1986) yields an annual average concentration of 15.1 $\mu g/m^3$.
(c) Assuming a first quarter concentration of 19.3 $\mu g/m^3$ (WCC, 1986) yields an annual average concentration of 13.7 $\mu g/m^3$.
(d) The annual average was calculated as the arithmetic mean of the available quarterly averages.
(e) Ignoring the first quarter average yields an annual average concentration of 14.3 $\mu g/m^3$.
(f) The first quarter concentration was not used in calculating the annual average.

BOIT774/034.51/jmc

Figure 2.5

Annual Mean Air Lead Concentrations



Data from Table 2.11

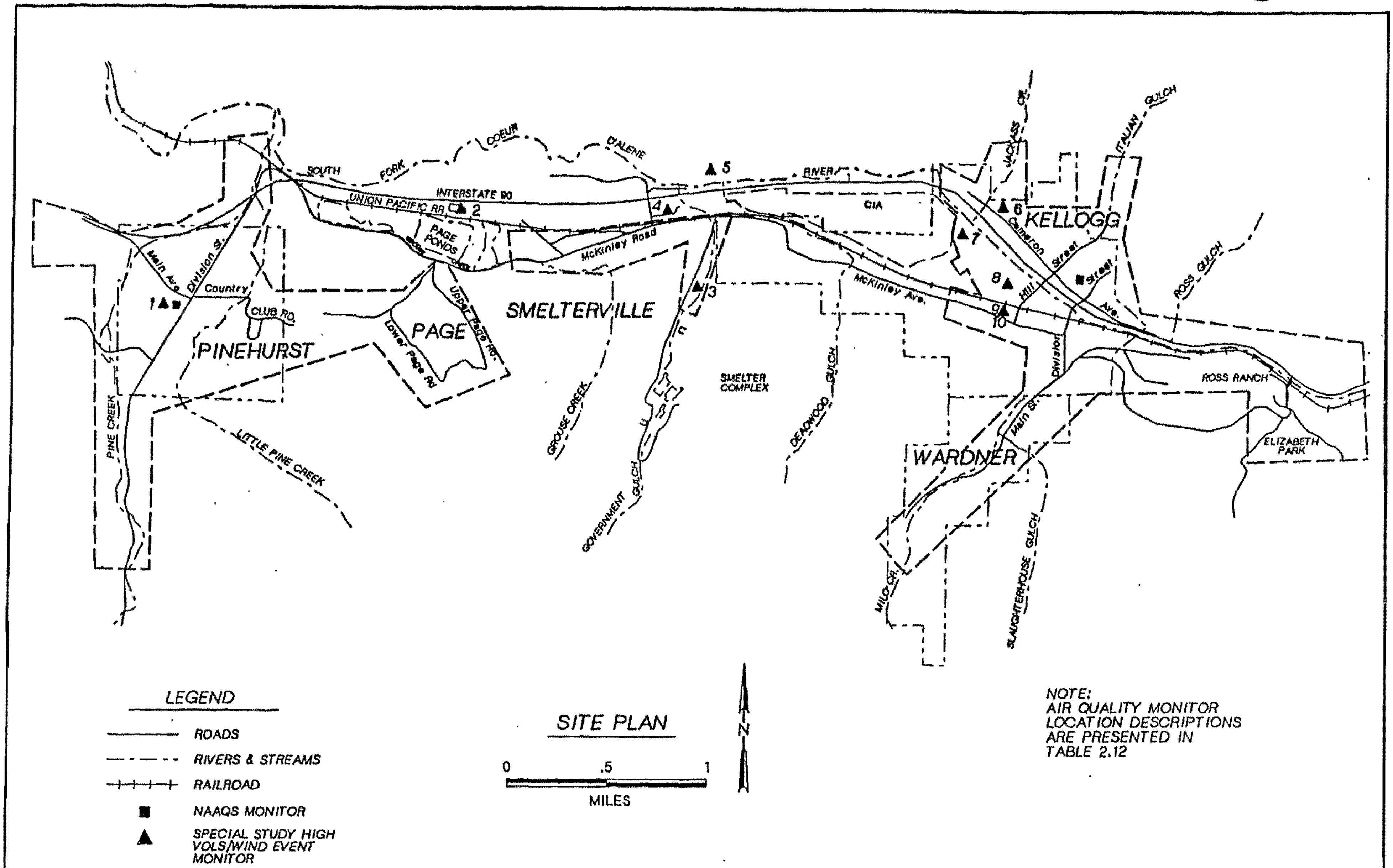


FIGURE 2.6
BUNKER HILL POPULATED AREA AIR QUALITY MONITOR LOCATIONS

depending on wind speeds and surface moisture conditions. Lead levels have generally followed TSP readings in recent years with levels being highest near the smelter complex.

2.2.1.2 Event Monitoring

For several years, investigators have noted extreme atmospheric particulate and lead loadings associated with high wind events and dry surface conditions in the valley (PedCo, 1975; PES, 1977; von Lindern, 1980; TG, 1986a). Regulatory authorities have received numerous complaints regarding windblown dusts from the smelter complex, Central Impoundment Area (CIA), and Smelterville Flats. Several RI/FS efforts were undertaken to investigate these wind and surface-related events. In the Populated Areas RI, a TSP monitoring network was assembled in 1986 and operated during the 1987 and 1989 seasons. The purpose of the network was to:

- Identify major sources of toxic elements, including lead, cadmium, and arsenic, by monitoring upwind and downwind from suspected sources.
- Assess health impacts for the populations living close to known toxic windblown dust sources.
- Operate the monitors and meteorological systems in order to collect and measure particulates during windy periods.

Specifications and operating plans for the monitoring system can be found in TG 1986d; CH2M HILL, 1987; CH2M HILL, 1990h).

The 1987 monitoring network consisted of 10 TSP monitors and a meteorological station located within the site boundaries. The locations of the monitors are shown in Figure 2.6. The monitor numbers and location descriptions are listed in Table 2.12. In 1989, the network was modified by eliminating the Kellogg Visitors Center location (#6) and adding PM_{10} monitors at the Drive-In Theatre/Truck Stop (#5a) and Kellogg Middle School (#7a).

Table 2.12

EVENT SAMPLER MONITORING

Monitor Number	Location Description
1	Pinehurst School
2	Smelterville Sewage Lagoon
3	Silver King School in Smelterville
4	Mine Timber Company at Smelterville
5	Drive-In Theatre/Truck Stop North of Smelterville
5a	Collocated PM-10
6	Kellogg Visitors Center
7	Kellogg Middle School
7a	Collocated PM-10
8	Mineral Subdivision in Kellogg
9	Shoshone Apartments in Kellogg
10	Collocated sampler at the Shoshone Apartments in Kellogg

In order to investigate particulate loadings associated with windblown dusts, total suspended particulate samples were collected daily, between 12:00 p.m. and 8:00 p.m. (PDT), from July 6 to October 31, 1987. This time period was selected based on typical weather and wind trace patterns for the area. Sixty-five percent of wind speeds exceeding 6 mph occurred during the 12:00 noon to 8:00 p.m. period during the sampling season. See Section 2.2.3 for meteorological monitoring results.

In 1987, a total of 1,210 filters were collected for TSP analysis including quality assurance and quality control samples. TSP concentrations are summarized in units of micrograms per cubic meter ($\mu g/m^3$) for the 8-hour period in Table 2.13a. In 1989, 576 filters were collected between July 7 and October 15. TSP concentrations for 1989 are summarized in Table 2.13b.

Table 2.13a shows that for the 12:00 noon to 8:00 p.m. monitoring period, TSP loadings averaged from 55 $\mu g/m^3$ at the Kellogg Visitor's Center (#6) to 87 $\mu g/m^3$ at Pinehurst (#1) for the July to November 1987 season. Maximum loadings occurred on September 2, 1987, for all locations and ranged from a low of 589 $\mu g/m^3$ at Pinehurst to 915 $\mu g/m^3$ at the Mine Timber (#4) location. Table 2.13a also shows that the majority of loadings throughout the year at all the sites, except Pinehurst, are less than 50 $\mu g/m^3$.

The frequency of low readings (<50 µg/m^3) ranges to as much as 76% of the observations at the Kellogg Middle School (#7). From 84 to 93% of the readings at all stations except Pinehurst are less than 100 µg/m^3. The percentage of readings exceeding 150 µg/m^3 for all stations ranged from 4 to 9% of the observations.

Table 2.13a

1987 AIR MONITORING TSP DATA (µg/m^3)

	Monitor Number 1	2	3	4	5	6	7	8	9	10
Minimum	13	10	8	10	4	11	6	8	5	6
Average	87	76	71	79	71	55	58	68	70	69
Maximum	589	853	821	915	811	722	904	691	690	744

Frequency Distributions

Loading Range (µg/m^3)		1	2	3	4	5	6	7	8	9	10
0 - 50	n	42	68	70	60	60	84	88	61	58	56
	%	36	59	60	52	52	72	76	53	54	55
50 - 100	n	47	39	29	39	37	24	19	42	32	30
	%	41	34	25	34	32	21	16	36	30	29
100 - 150	n	18	4	10	6	11	3	4	7	9	8
	%	16	3	9	5	9	3	3	6	8	8
Over 150	n	9	5	7	11	8	5	5	6	9	8
	%	8	4	6	9	7	4	4	5	8	8

Table 2.13b shows that in 1989 mean TSP levels were substantially lower at all stations except the collocated site at Shoshone Apartments. Based on an overall average, 1989 TSP concentrations were about 65 to 90% of corresponding 1987 levels on the east and west side of the site, respectively. Maximum levels were much lower, ranging from 278 to 682 µg/m^3 in 1989, as opposed to 589 to 915 µg/m^3 in 1987.

Table 2.13b

1989 AIR MONITORING TSP DATA ($\mu g/m^3$)

		Monitor Number									
		1	2	4	5	5a (PM-10)	7	7a (PM-10)	8	9	10
Minimum		10	9	8	6	6	0	2	8	0	20
Average		54	53	54	65	44	43	31	72	66	91
Maximum		309	349	345	683	321	278	127	390	398	341

Frequency Distributions

Loading Range ($\mu g/m^3$)		1	2	4	5	5a (PM-10)	7	7a (PM-10)	8	9	10
0 - 50	n	45	36	49	42	39	54	43	38	37	7
	%	69	74	71	61	83	78	90	55	56	28
50 - 100	n	15	9	15	19	4	11	2	16	19	11
	%	23	18	22	28	9	16	4	23	29	44
100 - 150	n	0	0	0	3	1	0	3	6	6	4
	%	0	0	0	4	2	0	6	9	9	16
Over 150	n	5	4	5	5	3	4	0	9	4	3
	%	8	8	7	7	6	6	0	13	6	12

The frequency of high TSP levels, however, was markedly different from 1987 only at Pinehurst where the percent of readings exceeding 100 $\mu g/m^3$ decreased from 24% to 8%. These data suggest that frequency of TSP levels were similar for the 2 years, but extreme events were less severe in 1989.

In 1987, extreme days account for a disproportionate amount of the total TSP loading observed over the 4-month period. The approximately 15% of days with TSP readings exceeding 100 $\mu g/m^3$ accounted for more than 40% of the total seasonal particulate loading in 1987. Days with individual TSP readings above 150 $\mu g/m^3$ (7% of the days) accounted for more than 30% of the total particulate loading for the entire sampling period.

In 1989, approximately 11% of readings had TSP values exceeding 100 $\mu g/m^3$ and these days accounted for more than 60% of the total loading for the sampling period. In both years these results suggest the major components of airborne particulate loading and subsequent migration are event-related.

In order to investigate the contaminant transport mechanisms associated with peak days, the State DEQ analyzed both the particulate loadings and metal content of filters and the meteorology from those days where at least one monitor recorded values exceeding 150 $\mu g/m^3$ TSP. The concentration value of 150 $\mu g/m^3$ was used as the metals analysis threshold level because this was the secondary TSP ambient air quality standard at the beginning of the project. Metal analytes included aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. Filters collected on the following 19 days were selected for metals analysis for 1987: July 15, 17, 28, 29; August 4, 28; September 2, 17, 22, 23, 25, 26; and October 3, 7, 25, 27, 28, 29, and 30. Filters collected on October 14 and 24, 1987 were inadvertently not selected for metals analysis. Only 10 days, all from September and October, were selected for 1989. Those days included September 8, 13, 15, 16, 25, 26, 27, 28, 29 and October 10, 1989.

Complete analytical results for metals are presented in CH2M HILL, 1990e. A summary of these data is shown in Tables 2.14a and b. Selected metals data are presented in concentration units of micrograms per cubic meter. Appendix A2.4 presents the results by day for both years with TSP, select metals loadings, metal content of the captured particulate, the mean wind speed and direction for the 8-hour sampling period, and the 1-, 3-, and 6-day precipitation totals.

The relative impacts of these days are remarkable. The 19 days in 1987 account for 43% of the total TSP loading for the entire 116-day sampling season. The single highest day (September 2, 1987) alone accounted for nearly 10% of the total monitoring season loading. In 1989, the peak 10 days accounted for 48% of the loading for the 90-day monitoring period.

Table 2.14a

SUMMARY OF AIR FILTER METALS DATA (μg/m³)
1987 Event Monitoring

	Monitor Number 1	2	3	4	5	6	7	8	9	10
Analyte: Arsenic										
Minimum	0.004	0.005	0.004	0.004	0.002	0.003	0.005	0.004	0.003	0.003
Average	0.008	0.022	0.020	0.028	0.021	0.017	0.039	0.052	0.065	0.087
Maximum	0.014	0.176	0.089	0.103	0.095	0.131	0.415	0.287	0.382	0.625
Analyte: Cadmium										
Minimum	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001	0.001
Average	0.002	0.005	0.012	0.008	0.010	0.007	0.015	0.018	0.032	0.039
Maximum	0.002	0.028	0.062	0.033	0.086	0.058	0.151	0.110	0.155	0.237
Analyte: Copper										
Minimum	0.074	0.074	0.056	0.038	0.089	0.017	0.061	0.052	0.044	0.034
Average	0.204	0.169	0.165	0.109	0.144	0.066	0.130	0.145	0.203	0.184
Maximum	0.437	0.233	0.489	0.217	0.259	0.172	0.364	0.490	0.616	0.761
Analyte: Lead										
Minimum	0.041	0.061	0.090	0.047	0.044	0.030	0.033	0.040	0.039	0.031
Average	0.224	0.703	0.997	1.067	1.059	0.382	0.656	1.214	1.799	2.400
Maximum	1.713	3.914	8.591	4.955	4.394	2.874	6.263	7.825	10.007	15.460

Table 2.14b

SUMMARY OF AIR FILTER METALS DATA ($\mu g/m^3$)
1989 Event Monitoring

	Monitor Number									
	1	2	4	5	5A	7	7A	8	9	10
Analyte: Arsenic										
Minimum	0.004	0.004	0.004	0.004	0.003	0.004	0.003	0.004	0.008	0.012
Average	0.008	0.007	0.010	0.009	0.006	0.010	0.008	0.031	0.022	0.022
Maximum	0.027	0.010	0.032	0.019	0.017	0.028	0.021	0.098	0.059	0.060
Analyte: Cadmium										
Minimum	0.003	0.005	0.003	0.003	0.003	0.003	0.004	0.005	0.005	0.004
Average	0.006	0.006	0.007	0.006	0.005	0.005	0.006	0.015	0.018	0.024
Maximum	0.021	0.010	0.023	0.014	0.008	0.008	0.009	0.053	0.062	0.094
Analyte: Copper										
Minimum	0.064	0.019	0.076	0.048	0.011	0.096	0.019	0.038	0.057	0.092
Average	0.133	0.119	0.132	0.073	0.045	0.354	0.053	0.121	0.176	0.134
Maximum	0.293	0.185	0.257	0.107	0.117	0.712	0.083	0.217	0.317	0.227
Analyte: Lead										
Minimum	0.058	0.053	0.120	0.078	0.045	0.054	0.027	0.139	0.242	0.180
Average	0.091	0.103	0.607	0.542	0.193	0.202	0.124	1.544	1.033	1.179
Maximum	0.189	0.296	3.553	1.611	0.690	0.517	0.437	4.157	2.879	4.013

2.2.2 Deposition Monitoring

Following the State's effort, the PRP collected TSP, particulate deposition, and meteorological data at the Mine Timber and Kellogg Middle School (#4 and #7) sites from November 1987 to November 1988 (Dames & Moore, 1990c). Daily TSP samples and continuous wind trace monitoring were conducted and weekly wet and dry deposition samples were collected using an Aero Chemetrics Model 301 Wet/Dry sampler.
Table 2.15 summarizes TSP statistics for the two stations. These filters were composited by week and analyzed for several metals.

Table 2.15

SUMMARY TOTAL SUSPENDED PARTICULATE LOADINGS ($\mu g/m^3$)
1988 - SMELTERVILLE MINE TIMBER AND KELLOGG MIDDLE SCHOOL SITES

SMELTERVILLE MINE TIMBER (Site #4)

	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Arithmetic Mean	63	53	60	93	55	48	39	47	60	118	123	80	34
Geometric Mean	56	48	54	78	45	35	31	40	45	104	79	71	29
Maximum	136	113	121	210	140	185	227	140	214	358	795	189	74
Minimum	20	13	24	24	13	9	10	18	17	52	15	23	15
Number of Obs.	23	31	29	29	31	30	31	29	31	31	30	31	7

KELLOGG MIDDLE SCHOOL (Site #7)

	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Arithmetic Mean	38	36	41	62	32	25	29	31	36	53	65	49	18
Geometric Mean	34	30	35	54	26	21	22	27	28	45	38	41	16
Maximum	78	88	86	128	113	63	165	69	153	228	586	219	44
Minimum	13	7	12	17	7	5	8	6	11	21	10	17	11
Number of Obs.	24	30	29	29	31	30	31	29	31	31	30	31	7

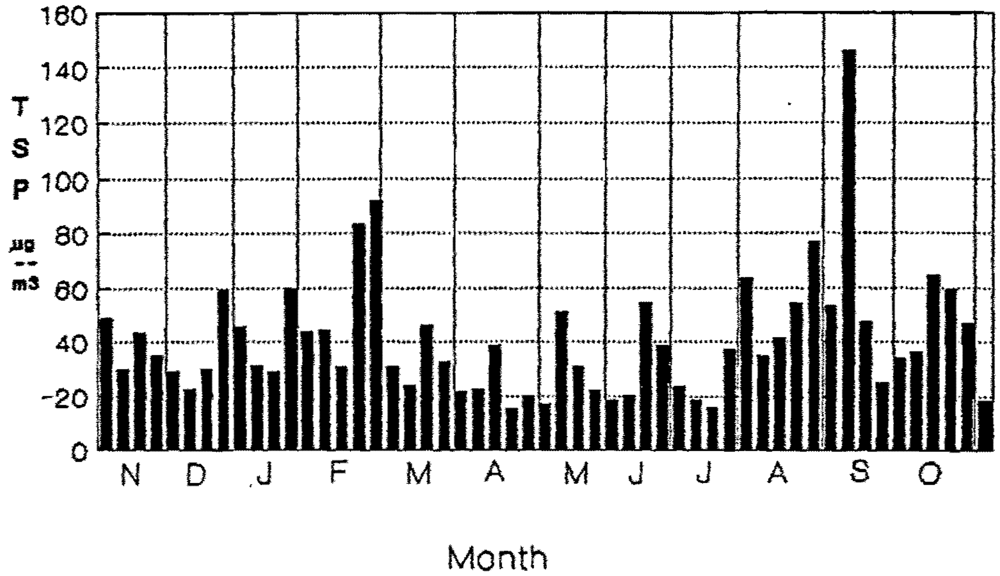
Adapted from Dames & Moore, 1990c.

The composited results are shown in Figures 2.7 and 2.8 and summarized in Table 2.16. Complete results can be found in Appendix A2.5. Table 2.17 shows individual metals analyses for those filters with TSP loadings exceeding 150 $\mu g/m^3$.

These results are not directly comparable to the previous year's monitoring effort by the State DEQ because of the differences in sampling period (8 versus 24 hours and 5 versus 12 months). However, no inconsistencies between the two sets of data are obvious.

FIGURE 2.7

Weekly Composited Suspended Particulate and Air Lead Concentrations - Kellogg 1988



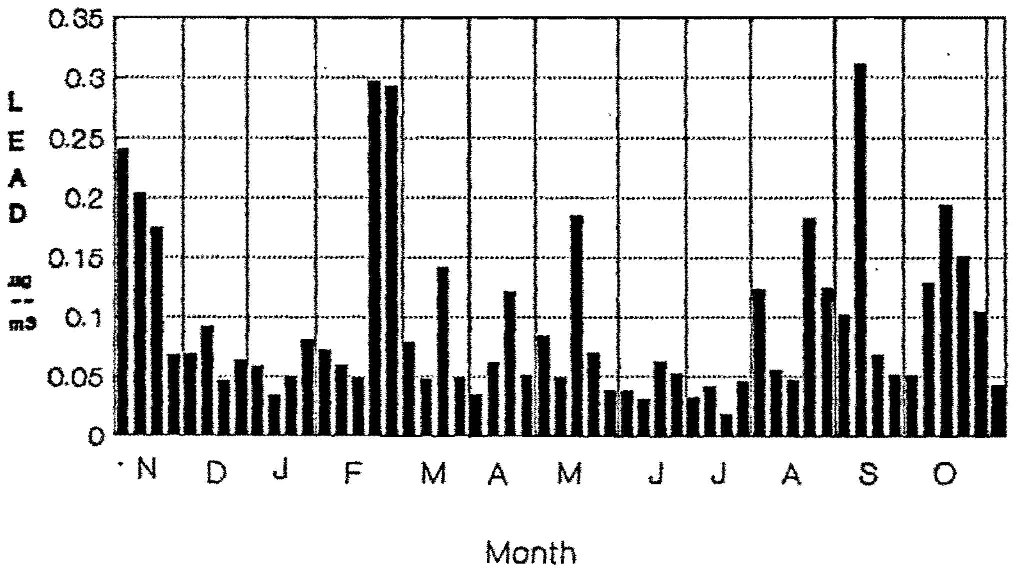


FIGURE 2.8

Weekly Composited Suspended Particulate and Air Lead Concentrations - Smelterville 1988

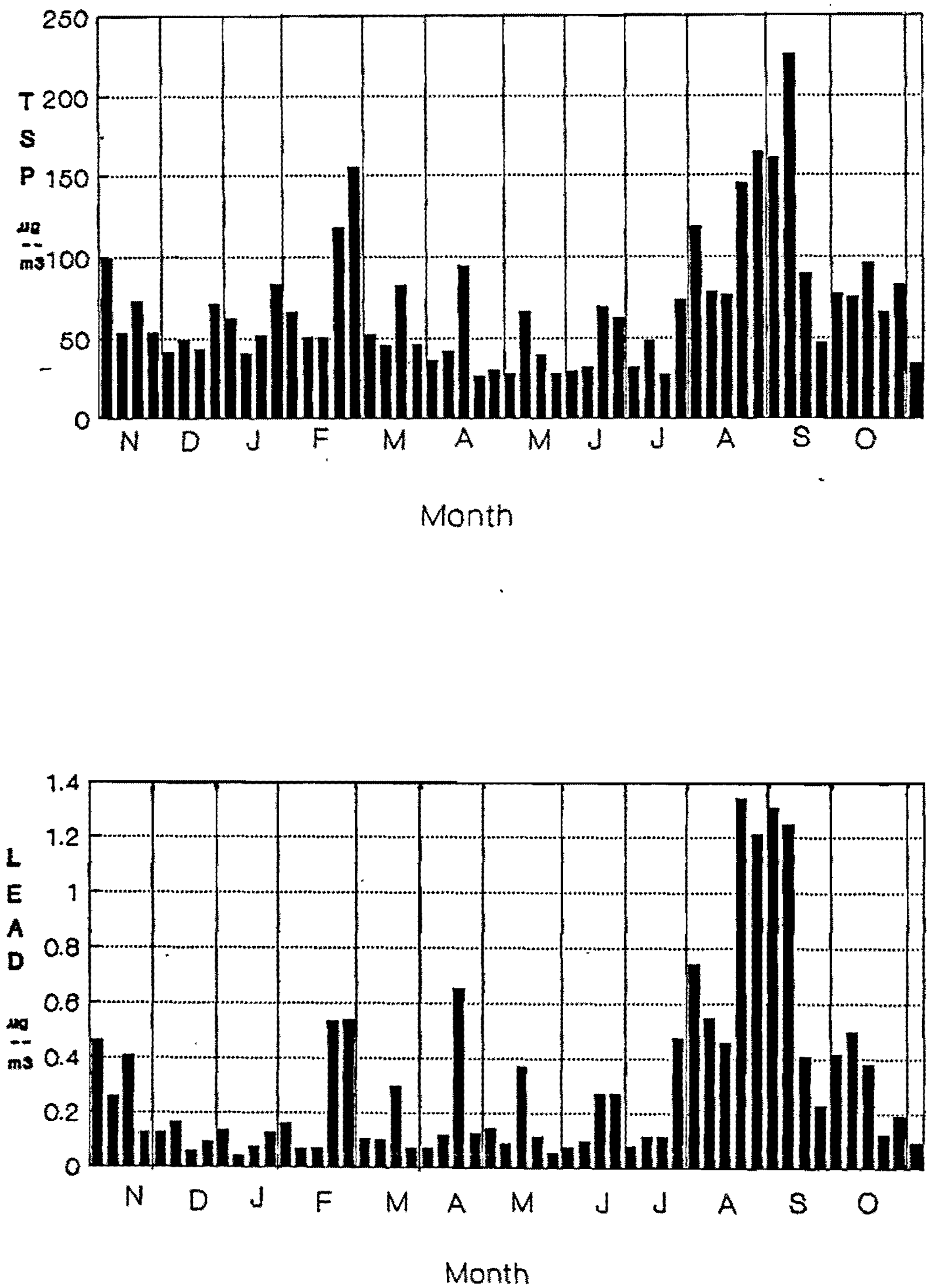


Table 2.16

SUMMARY OF 1988 WEEKLY COMPOSITE TSP LOADING AND DRY DEPOSITION TOTALS

	Kellogg Middle School (#7)	Smelterville Mine Timber (#4)
Suspended Particulate		
TSP ($\mu g/m^3$)		
Min	15.3	26.8
Mean	40.8	69.5
Max	146.4	225.2
Cd ($\mu g/m^3$)		
Min	<.001	<.001
Mean	0.002	0.003
Max	0.005	0.017
Pb ($\mu g/m^3$)		
Min	0.018	0.044
Mean	0.095	0.312
Max	0.310	1.35
Dry Deposition		
Solids ($\mu g/m^2/hr$)		
Min	177	178
Mean	1767	2532
Max	10482	12595
Cd ($\mu g/m^2/hr$)		
Min	0.01	0.02
Mean	0.08	0.11
Max	0.65	0.43
Pb ($\mu g/m^3/hr$)		
Min	0.72	0.82
Mean	3.99	12.7
Max	18.3	83.8

Adapted from Dames & Moore, 1990c.

Figures 2.7 and 2.8 show the seasonal effects in TSP as suspended metal loadings. The highest concentrations of particulates occurred in late winter and late summer. The most significant metals loadings in 1988 occurred in late February and in late August through November.

Table 2.17

INDIVIDUAL FILTERS WITH TSP >150 μg/m³
Nov. 1987 - Nov. 1988

SMELTERVILLE MINE TIMBER

SAMPLE DATE	TSP (μg/m³)	Cd (μg/m³)	Cd (μg/gm)	Pb (μg/m³)	Pb (μg/gm)
880906	795.1	0.012	15	3.9	4948
880903	508.4	0.033	65	5.8	11413
880829	357.6	0.006	17	1.9	5180
880820	307.9	0.013	43	3.5	11352
880825	305.3	0.007	24	2.6	8545
880907	253.4	0.006	24	1.5	5985
880512	227.3	0.011	49	1.5	6517
880909	225.6	0.006	28	1.8	7844
880727	214.3	0.005	25	1.5	6943
880222	209.5	0.007	35	0.7	3560
880224	197.9	0.007	34	0.6	3033
880223	190.8	0.007	39	0.7	3826
881021	189.4	0.003	16	0.2	1282
881003	189.2	0.011	59	1.7	9118
880413	185.2	0.017	90	1.6	8894
880414	181.8	0.014	78	1.6	8534
880225	175.2	0.007	41	0.6	3382
880711	170.6	0.001	5	0.2	1210
880830	170.1	0.002	13	1.0	5687
880801	160.9	0.003	18	1.2	7394
880916	160.1	0.004	24	0.4	2654
880226	159.4	0.006	37	0.5	3339
880915	158.9	0.003	21	0.8	5139
881015	158.3	0.000	3	0.0	181

KELLOGG MIDDLE SCHOOL SITES

SAMPLE DATE	TSP (μg/m³)	Cd (μg/m³)	Cd (μg/gm)	Pb (μg/m³)	Pb (μg/gm)
880906	594.4	0.068	114	1.5	2568
880906	585.6	0.063	107	1.5	2509
880829	227.6	0.005	21	0.2	852
881021	219.0	0.010	44	0.6	2721
880819	208.8	0.001	5	0.1	380
881021	205.3	0.006	30	0.5	2475
880512	165.0	0.007	42	0.3	1816
880907	154.7	0.011	72	0.3	2008
880512	153.1	0.005	35	0.3	1892
880711	152.6	0.000	3	0.0	215
881015	150.8	0.000	2	0.0	88

Wind speed, direction, and stability frequencies were also recorded for the monitoring period. Those data are summarized in Section 2.2.3. These results show that high wind speeds in this area tend to occur under particular atmospheric conditions. More than 75% of all winds exceeding six knots (7 mph) occur under neutral atmospheric conditions (C and D stability categories). More than three-fourths of these winds originate from the west in the W, WNW, and WSW sectors. These observations are consistent with the meteorological observations associated with dust events in the 1987 and 1989 State DEQ event-monitoring efforts. These high wind speeds are also seasonal with 67% occurring between March and September. See Section 2.2.3 for a discussion of meteorological monitoring.

Concurrent with the 1988 ambient monitoring, the PRP conducted both wet and dry deposition studies during the year November 1987 to November 1988. Wet and dry deposition represent the two mechanisms by which particulate matter and air pollutants are removed from the atmosphere. Wet deposition occurs by absorption of contaminants into droplets of water, followed by removal by precipitation (i.e., rain and snowfall). Dry deposition is the uptake of particles and gases accomplished at the earth's surface by soil, water or vegetation (for example, settling of dust particles from the atmosphere). Particle settling likely accounts for most airborne contaminant migration at this site.

Dry deposition rates were shown concurrently with TSP and atmospheric metal loadings composited by week in Figures 2.7 and 2.8 and summarized in Table 2.16. Total dry particulate deposition rates average 2,532 $\mu g/m^2/hr$ and 1,768 $\mu g/m^2/hr$ at the Smelterville Mine Timber and Kellogg Middle School sites, respectively. Wet deposition rates averaged 484 and 487 $\mu g/m^2/hr$ at the Smelterville and Kellogg sites, respectively. More than 80% of the total particulate and more than 90% of most metals deposition occurs as dry deposition. The remainder of this report discusses either dry or combined deposition. The maximum dry deposition rate observed was 12,595 $\mu g/m^2/hr$ at the Mine Timber site during the second week of September 1988. Only four metals were observed to have dry deposition rates consistently exceeding 1.0 $\mu g/m^2/hr$. Those were iron, lead, manganese, and zinc with annual average deposition rates at the Mine Timber site of 132, 12.7, 8.6, and 11.3 $\mu g/m^2/hr$, respectively. The maximum weekly lead deposition rate observed was 83.8 $\mu g/m^2/hr$ at the Mine Timber site, also occurring during the second week of September.

Deposition seems to follow TSP values fairly consistently. However, the best indicator of high deposition rates for both total solids and metals seems to be the occurrence of severe event days. The highest deposition rates were observed during the weeks that also included the severe (>150 $\mu g/m^3$) dust event days shown in Table 2.17. The 1988 data confirm that both total solids and contaminant particulate deposition seem to be event-related in a manner similar to the TSP and ambient air metals concentration discussed in the last section. At both sites, more than 25% of the total annual solids deposition occurred in four individual weeks in 1988. Those included one week in each of May, August, September and October. The same weeks accounted for 31% of total lead, 18% of total cadmium, and 29% of total arsenic deposition. The 1988 seasonal data also showed a frequency and magnitude of severe dust events (TSP >300 $\mu g/m^3$) similar to that observed in 1987, but absent in 1989.

These results suggest that deposition, similar to TSP, is event-related with the bulk of deposited solids and metals coming as a result of high wind speeds impacting barren dust sources in the vicinity of the monitors.

2.2.3 Meteorological Monitoring

Valley meteorology has been well understood since the intensive investigations undertaken in the early 1970s by the Bunker Hill Company to develop a sulfur oxides supplemental control system for the smelter. Characteristic weather patterns and their influence on contaminant transport and distribution have been described in Bunker Hill Co., 1976 and von Lindern, 1980. The valley meteorology is dominated by the mountain-valley drainage phenomena. Nighttime surface cooling leads to down-slope winds in the evenings as cooler dense air begins to flow downhill and eventually down-valley, setting up gentle east-to-west winds ranging from 1 to 2 mph. A nocturnal inversion layer generally forms over this drainage at elevations varying from 1,000 to 2,000 feet above the valley floor.

Morning insolation and the associated surface warming initiates fumigation-like atmospheric behavior (intense surface-based turbulence) that culminates in inversion breakup around 10:00 to 11:00 a.m. in summer months. Continued insolation results in warming of the air near the surface and up-slope/up-valley winds. These winds generally reach maximum velocity during early to mid-afternoon and reverse direction in the early evening. The wind speed and persistence are dependent on the intensity of insolation and synoptic conditions. This pattern is evident on more than 80% of the days in the valley. The most severe particulate reentrainment episodes occur when regional frontal conditions (squall lines) combine with the diurnal patterns to produce extreme wind speeds combined with dry surface conditions. This combination is rare (i.e., 5-15 days per year), but can occur on afternoons throughout the spring, late summer and early fall (especially September) depending on synoptic pressure gradients, local heating, and recent precipitation factors. On rare occasions (2 or 5 days per year), intense winds can come from the east when synoptic conditions combine with the mountainous terrain to produce severe orographic drainage winds.

Wind speed, direction, temperature, barometric pressure, and precipitation have been monitored at a central valley location (Smelterville Mine Timber Site #4) since June 1987. The observed wind trace is illustrative of the meteorologic phenomena discussed above. Figure 2.9 shows a typical 24-hour wind trace (0=24=midnight) for the site. Low nighttime wind speeds (<2 mph) are noted. Wind speed increases begin in late morning and peak at 7 mph between 1 and 4 P.M. Wind speeds fall quickly and reverse direction shortly after sunset that occurs from 5 to 6 P.M. in the mountain terrain in this season.

Figure 2.10a shows the standard windrose for the 1987 sampling period, July to November 1987, and Figure 2.10b shows the annual windrose for 1988. Both of these figures show that the predominant wind direction is from the W-WSW. The majority of high wind speeds originate directly from the west, particularly in the dry season as indicated by Figure 2-10a.

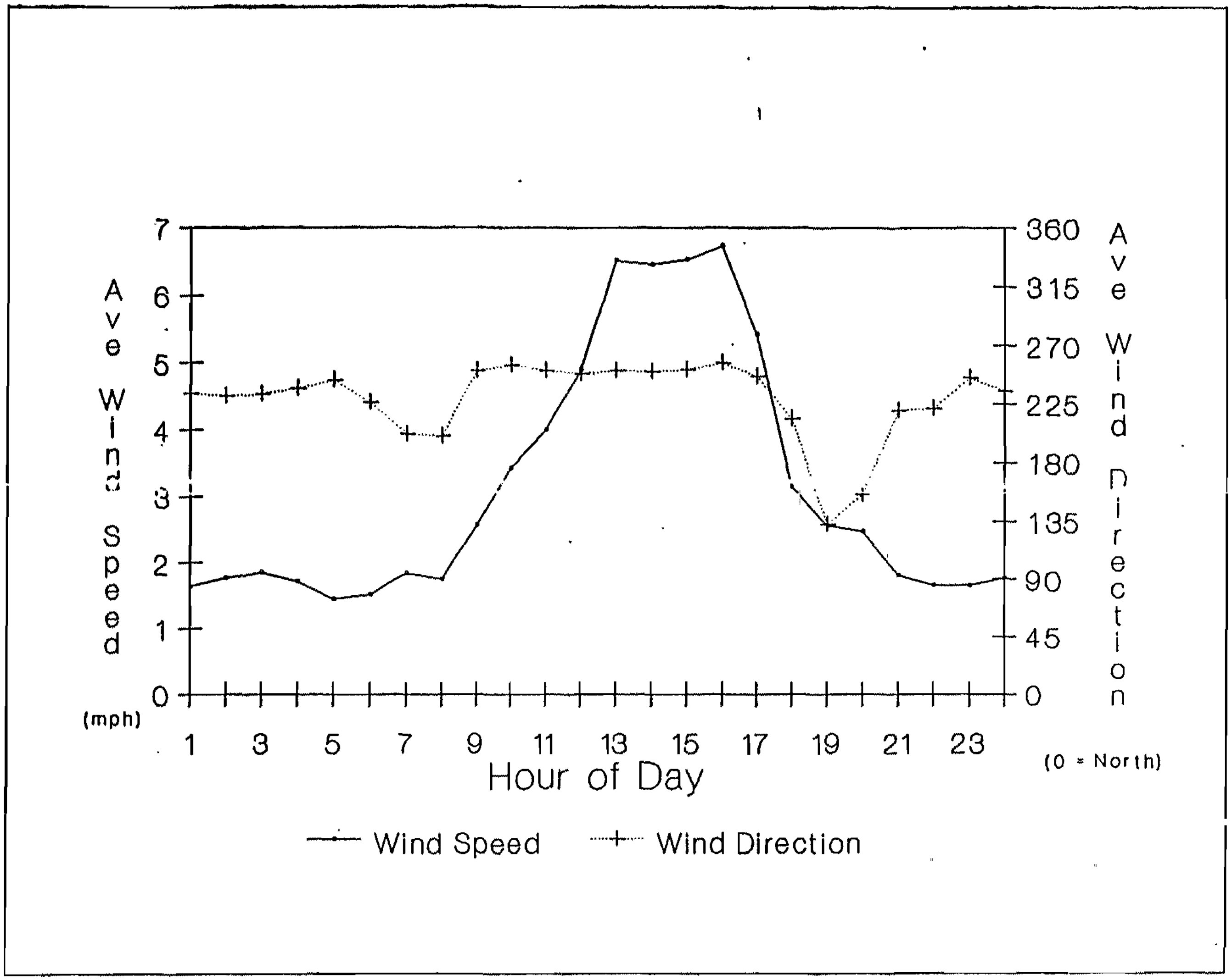


FIGURE 2.9

Typical Daily Wind Speed and Direction for the Bunker Hill Site

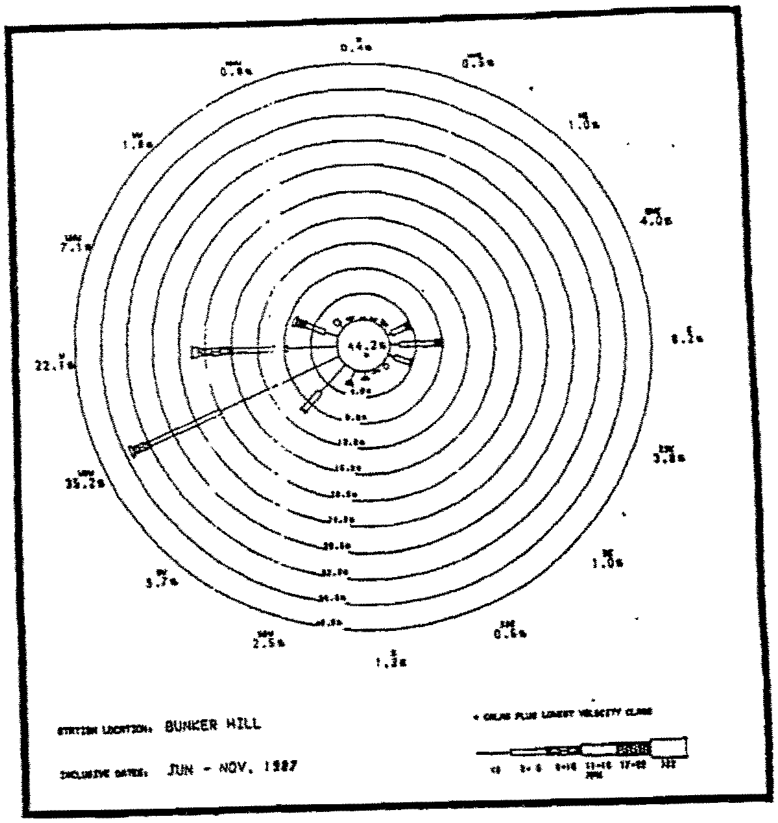


FIGURE 2.10a
Hourly Average Surface Winds Percentage Frequency of Occurrence (1987 Event Monitoring Period)

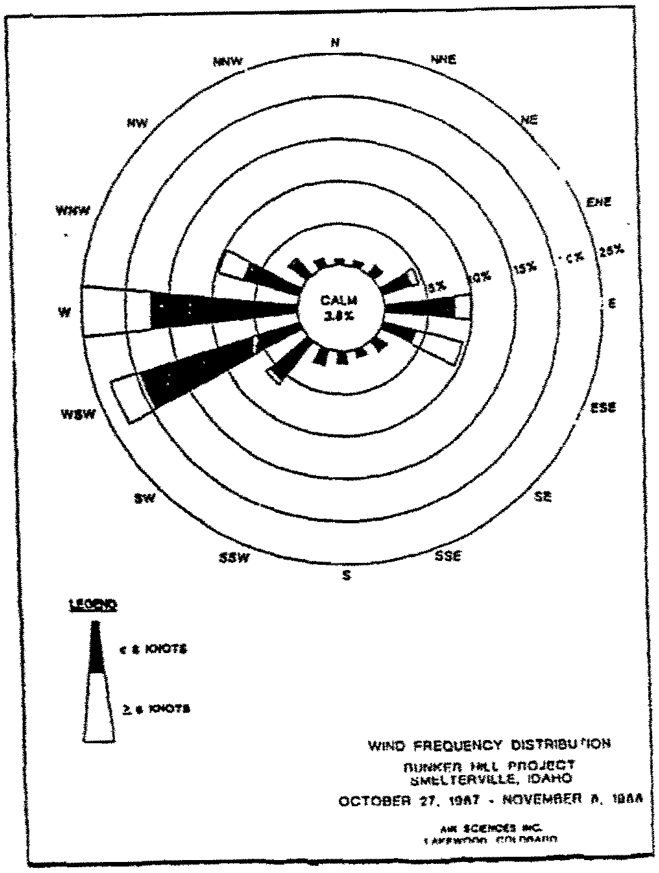


FIGURE 2.10b
Standard Wind Rose - Wind Frequency Distribution Nov. 1987 - Nov. 1988

The 1988 meteorologic monitoring effort also estimated Gifford-Pasquill stability categories for the various observations. Gifford-Pasquill stability categories empirically describe atmospheric turbulence as the standard deviation in pollutant concentrations in the horizontal and vertical directions as a function of downwind distance. The greatest dispersion of contaminants occurs under the most unstable conditions (A-stability). The least dispersion, or highest concentrations occur under extremely stable conditions (F-stability). Neutral conditions, or those where vertical displacement of the atmosphere is not enhanced, are represented by C and D stability categories. Table 2.18 summarizes Wind Speed, Direction and Stability Category frequencies for the 1988 data base. These results show that high wind speeds occur in this valley under fairly well prescribed conditions. More than 75% of winds in excess of 7 mph originate out of the WNW, W, WNW sectors (up-valley) under C and D (neutral) stability. Most of the remainder (14%) of the high wind speeds are directly opposed (down-valley) out of the E and ENE under D stability conditions.

Table 2.18
WIND DIRECTION AND STABILITY FREQUENCIES FOR > SEVEN MPH WINDS
SHELTERVILLE MINE TIMBER SITE - 1988

Direction	Stability Category A	B	C	D	E	F	% of >7 mph winds by direction
N	0.02	0.00	0.00	0.00	0.00	0.00	0.1
NNE	0.02	0.00	0.00	0.00	0.00	0.00	0.1
NE	0.02	0.04	0.05	0.08	0.01	0.00	1.0
ENE	0.11	0.02	0.05	0.55	0.10	0.00	4.5
E	0.11	0.05	0.20	1.33	0.06	0.00	9.5
ESE	0.07	0.04	0.08	0.26	0.01	0.00	2.4
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.0
SSE	0.02	0.00	0.00	0.00	0.00	0.00	0.1
S	0.02	0.00	0.00	0.00	0.01	0.00	0.2
SSW	0.04	0.04	0.00	0.02	0.01	0.00	0.6
SW	0.13	0.19	0.07	0.11	0.01	0.00	2.7
WSW	0.38	0.74	1.25	1.01	0.05	0.00	18.4
W	0.47	1.00	2.03	4.45	0.05	0.00	43.0
WNW	0.25	0.32	0.84	1.50	0.01	0.00	15.7
NW	0.04	0.01	0.07	0.11	0.01	0.00	1.3
NNW	0.02	0.02	0.00	0.02	0.00	0.00	0.3
% of > 7 mph winds by Stability Category	9.3	13.3	24.8	50.6	1.9	0.0	

Adapted from Dames & Moore, 1989d.

2.3 House Dusts

Metal contaminant levels in house dusts are available from the 1974, 1975, 1983, and 1988 IDHW/PHD Health Surveys. Several sample types were collected in these surveys. These data were summarized in JEG et al., 1989. Results used for evaluating population exposures in the human health risk assessment are those collected in the domestic vacuum cleaner bag. This sample type has been collected in each of the surveys since 1974. Metals levels in these samples represent concentrations from integrated sampling of areas the homemaker regularly maintains. Table 2.19 presents the mean and extreme house dust metal concentrations for the period 1974 through 1988 grouped according to area. Extreme concentrations represent the calculated 95 percentile levels based on a log-normal distribution of house dust metal concentrations. Cumulative distribution plots for 1983 and 1988 house dust lead concentrations are provided in Appendix 3A, Figures A3.4 and A3.5.

House dust metal contamination, and especially lead levels, has decreased markedly since 1974. For example, the mean house dust lead concentration in Smelterville for 1974 was approximately 12,000 µg/gm (1.2%) and has decreased to a mean level in 1988 that is one-tenth the 1974 value (1,200 µg/gm). Prior to 1981, during smelter operations, the primary route for house dust lead contamination was airborne deposition of smelter lead particulate matter. Since 1981, house dust metals are associated with soils and reach homes via deposition of windblown dusts or mechanical translocation of contaminated residential soils. Several studies indicate house dust lead levels in urban and smelter communities (exclusive of those impacted by interior leaded paints) are dependent on lead levels in residential soils. JEG et al., 1989 provides detailed analyses of these relationships.

Table 2.19

GEOMETRIC MEAN AND EXTREME HOUSE DUST METAL CONCENTRATIONS
1974, 1975, 1983 AND 1988 LEAD HEALTH SURVEY (µg/gm)

		As	Cd	Cu	Hg	Pb	Sb	Zn
1974								
Smelterville	Mean	8.0	113.0	-	17.8	10583	185.0	5432
	(95%ile)	(28.5)	(503.0)		(109.0)	(30394)	(409.0)	(17154)
Kellogg/Wardner/Page	Mean	5.7	65.5	-	7.3	6,581	174.0	3940
	(95%ile)	(40.3)	(227.0)		(66.6)	(23017)	(844.0)	(9575)
Pinehurst	Mean	3.3	29.5	-	3.5	2006	120.0	2695
	(95%ile)	(15.9)	(73.5)		(11.9)	(5453)	(312.0)	(6515)
1975								
Smelterville	Mean	-	42.0	-	-	3533	-	-
	(95%ile)		(159.0)			(21807)		
Kellogg/Wardner/Page	Mean	-	44.7	-	-	4573	-	-
	(95%ile)		(122.0)			(13521)		
Pinehurst	Mean	-	25.0	-	-	1749	-	-
	(95%ile)		(81.5)			(6694)		
1983								
Smelterville	Mean	-	63.3	-	-	3715	-	2695
	(95%ile)		(123.5)			(7754)		(5070)
Kellogg/Wardner/Page	Mean	-	37.6	-	-	2366	-	2443
	(95%ile)		(93.0)			(7840)		(10373)
Pinehurst	Mean	-	24.6	-	-	1155	-	1578
	(95%ile)		(68.3)			(3255)		(3301)
1988								
Smelterville	Mean	25.7	15.4	177.0	1.3	1203	18.9	1394
	(95%ile)	(80.0)	(52.0)	(1,073.0)	(7.8)	(4615)	(64.0)	(4309)
Kellogg/Wardner/Page	Mean	26.3	15.6	167.0	1.3	1450	27.9	1401
	(95%ile)	(115.0)	(47.0)	(963.0)	(4.6)	(8643)	(147.0)	(5143)
Pinehurst	Mean	-	-	-	-	-	-	-
	(95%ile)							

- Data not available. Exposure estimates will employ concentration from most recent measurements.
Source: IDHW 1974, 1975, 1983 and 1989b.

BOIT790/04851-pc/jmc

3.0 SITE-SPECIFIC CONCENTRATIONS OF CONTAMINANTS OF CONCERN COMPARED TO ARARs AND TBCs

State and federal ARARs (applicable or relevant and appropriate requirements) and TBCs (to-be-considered materials) for the Populated Areas of the Bunker Hill site are identified and discussed in Section 6 of the PD (JEG et al., 1989). ARARs and TBCs are generally referenced as cleanup standards and/or guidelines for remedial actions at Superfund sites. The chemical-specific ARARs and TBCs presented in this section are those that are expected to be protective of public health.

Site-specific concentrations of contaminants found in environmental media of the Populated Areas are compared to ARARs, when they are available. In addition to the laws and regulations, many federal and State environmental and public health programs also develop criteria, advisories, guidances and proposed standards that, although not legally binding, may provide critical health-based information or recommendations. These materials are referred to as "to be considered" (TBC) materials. In specific cases, a risk assessment can be based on the application of health-based criteria derived from TBCs.

ARARs and TBCs referenced in this section are a subset of all chemical-specific ARARs and TBCs identified for the Populated Areas. Only the standards and guidelines that provide specific numerical values, and for which there are comparable site data, are presented. For several of the chemicals of concern and relevant media pathways, appropriate ARARs or TBCs do not exist. In those instances, the risk assessment process will be used to establish cleanup goals. Site-specific data regarding blood lead levels in the resident childhood population are also discussed with consideration of recent health-based guidances concerning lead absorption in children.

3.1 Soil and Dust

There are currently no promulgated laws or standards which provide numerical thresholds that serve as ARARs for soil and dust contamination. However, TBCs have been developed that address threshold levels of lead in soil and dust. These TBCs include:

- Centers for Disease Control (CDC) Soil/Dust Lead-Contamination Advisory, Preventing Lead Poisoning in Young Children: A Statement from the Centers for Disease Control. Atlanta. U.S. Dept. of Health and Human Services, January 1985.
- USEPA Guidance Concerning Soil Lead Cleanup Levels at Superfund Sites, OSWER Directive #9355.4-02. Office of Solid Waste and Emergency Response, September 1989.

CDC's 1985 statement on childhood lead poisoning provides the following guidance:

> "In general, lead in soil and dust appears to be responsible for blood levels in children increasing above background levels when the concentration in the soil or dust exceeds 500-1,000 ppm."

This advisory is consistent with the September 1989 USEPA (1989a) interim directive concerning soil lead cleanup levels at Superfund sites.

Data representing lead levels in residential yard soils are available from the 1986/87 Bunker Hill Populated Area RI/FS (CH2M HILL, 1990a; see Section 4 of the PD and Section 2 of this report). The reported concentrations are compared to the CDC/ USEPA soil lead target levels in Table 3.1. Mean background level of soil lead is also provided in Table 3.1 for comparison. Figures A3.1 through A3.3 and Table A3.1 in Appendix A present soil lead concentration statistics and distributions since 1983. Approximately 95% of the residential yard soil lead concentrations in Smelterville, Kellogg, Wardner and Page are greater than 500 $\mu g/gm$ (ppm) and approximately 85% of the yard surficial soil lead concentrations are greater than 1,000 $\mu g/gm$. A 1989 survey of Pinehurst residential soils shows that approximately 50% of the soil lead concentrations

Table 3.1
Site-Specific Concentrations of Lead in Soil and House Dust Compared to TBCs

Soil Lead-Contamination Advisory Levels[a] (µg/gm)	Site-Specific Lead Concentrations[b] 1986-1987: Smelterville (µg/gm)	Site-Specific Lead Concentrations[b] 1986-1987: Kellogg/Wardner/Page (µg/gm)	Background, Northern Rural Idaho[c] (µg/gm)
500-1,000	Mean 2,685	Mean 1,988	43
	95%ile 10,432	95%ile 7,021	
	96.1% ≥ 500	95.1% ≥ 500	
	88.6% ≥ 1,000	83.4% ≥ 1,000	

Dust Lead-Contamination Advisory Levels[a]	Site-Specific Lead Concentrations[b] 1988: Smelterville (µg/gm)	Site-Specific Lead Concentrations[b] 1988: Kellogg/Wardner/Page (µg/gm)	Background Rural U.S.[d] (µg/gm)	Anaconda[e] Smelter Site, Mill Creek, Montana 1987 (µg/gm)
500-1,000	Mean 1,203	Mean 1,450	50-500	133-470
	95%ile 4,615	95%ile 8,643		
	90% ≥ 500	88.5% ≥ 500		
	60% ≥ 1,000	72.1% ≥ 1,000		

(a) CDC 1985; U.S. EPA Guidance Concerning Soil Lead Cleanup Levels at Superfund Sites, OSWER Dir #9355-02. Office of Solid Waste and Emergency Response. September 1989.
(b) CH2M HILL, 1990a; see also Table 4.5 of the Protocol document for soil-lead data; see also Table 4.7 of the Protocol document for house dust-lead data.
(c) Gott and Cathrall, 1980.
(d) U.S. EPA 1989a.
(e) Clement Associates, 1987.

are greater than 500 μg/gm (ppm) and approximately 20% are greater than 1,000 μg/gm. Soil litter (upper organic layer) lead concentrations are generally greater than those exhibited by the associated mineral soils.

Recent measurements of contaminant levels in residential house dusts are available from the 1988 IDHW Health Survey and are discussed in Section 4.3.2 of the PD and in Section 5 of this report. The reported concentrations of lead in house dust are also compared to the CDC/USEPA soil lead cleanup levels in Table 3.1. Figures A3.4 and A3.5 and Table A3.1 in Appendix A present house dust lead concentration statistics and distributions since 1983. Recent site data (1988) for those homes surveyed (in Smelterville, Kellogg, Wardner and Page) indicate that approximately 85% of the house dust lead concentrations for the area are greater than 500 μg/gm and approximately 65% are greater than 1,000 μg/gm.

Data representing the other site contaminants of concern in residential surficial soil and house dust are compared to background soil levels (for northern rural Idaho) in Tables 5.2 and 5.3. There are currently no ARARs or TBCs for these soil and dust contaminants, and thus remedial goals will be based on the results of the site risk assessment.

ARARs under the Resource Conservation and Recovery Act (RCRA) and Land Disposal Restrictions require classification of wastes as either hazardous or nonhazardous. EPA has established two fundamentally different mechanisms for defining RCRA hazardous wastes: listed wastes and characteristic wastes:

- Listed wastes include specific wastes from non-specific sources, specific wastes from specific sources, and commercial chemical products.
- Characteristic wastes are broad classes of wastes which are clearly hazardous by virtue of an inherent property. Characteristic wastes include ignitability, corrosivity, reactivity, and Extraction Procedure (EP) toxicity.

An EP toxic waste is one for which the EP test extract contains concentrations of particular constituents of concern above their regulatory threshold. Similarly, a Toxicity Characteristic (TC) hazardous waste is one for which the TC test extract contains concentrations of particular constituents of concern above their regulatory threshold. Regulations are found in:

- Resource Conservation and Recovery Act (RCRA), Subtitle C - Characteristics of Hazardous Wastes. 42 U.S.C. 6901; 40 CFR Section 261.24 et seq.

- Idaho Hazardous Waste Management Act (HWMA), Idaho Code Sections 39-4401 through 39-4432; IDAPA Section 16.01.5005

- Resource Conservation and Recovery Act (RCRA), Subtitle C - Characteristics of Hazardous Wastes. 40 CFR Section 261.24 et seq. March 29, 1990 Federal Register (Effective date for TC rule is September 25, 1990).

The RCRA TC rule supersedes the EP rule as of September 25, 1990; however, the EP metal constituents and their regulatory levels are being retained under the TC rule. Metal constituents and their regulatory levels (in mg/L) are:

arsenic	5.0	lead	5.0
barium	100.0	mercury	0.2
cadmium	1.0	selenium	1.0
chromium	5.0	silver	5.0

Comparison of residential soil characteristics in terms of EP toxicity test results to regulatory levels is found in an IDHW memorandum dated June 20, 1990, presented in Appendix B. That comparison concludes that soil wastes resulting from removal of the top 6 or 12 inches of soil from residential yards are not a RCRA characteristic hazardous waste.

3.2 Air

3.2.1 Clean Air Act (CAA), 42 U.S.C. Sections 7401 et seq.; National Ambient Air Quality Standards (NAAQS), 40 CFR Part 50.

The Clean Air Act, and standards promulgated pursuant to the Act, the NAAQS, have been identified as potential ARARs for the Populated Areas of the Bunker Hill site (see Section 6 of the PD).

3.2.1.1 NAAQS for Chemicals of Concern

Ambient air quality data for the site is presented in Section 4 of the PD (JEG et al., 1989). Ambient air concentrations for lead and total suspended particulates (TSP) since 1971 are reported in Table 2.11 as results obtained from the Idaho Air Quality Monitoring Network, operated by the Air Quality Bureau of the Division of Environment of the Department of Health and Welfare. Ambient air concentrations for some of the other chemicals of concern have been estimated by developing metal-to-lead ratios utilizing air quality and dust data from various site studies (USEPA, 1989i; Cooper et al., 1980; Ragaini et al., 1977; WCC, 1986; Dames & Moore, 1990a; and CH2M HILL, 1990e). Estimated mean airborne metal concentrations are compared to background air quality data and presented in Table A3.2.

Lead is the only chemical of concern with an identified NAAQS. The NAAQS for lead is a 3-month (quarterly), arithmetic mean concentration of 1.5 $\mu g/m^3$. Comparison of the standard to recent air measurements for lead (in Table 2.11) shows the site to be in conformance with current regulations.

The USEPA has recently proposed a revision to the NAAQS for lead (USEPA, 1989c). The suggested revision lowers the NAAQS to a monthly average of 0.5 $\mu g/m^3$. The reassessment of the NAAQS for lead considers an evaluation of alternative standards based on the health risks associated with children's blood lead levels at and above

10 μg/dl. The USEPA Clean Air Scientific Advisory Committee (CASAC) (USEPA 1990a) has also indicated that health effects associated with blood lead levels above 10 μg/dl in sensitive populations clearly warrant concern. The value of 10 μg/dl refers to the maximum blood lead permissible for all members of sensitive groups, and not population mean or median values. The CASAC recognizes that there is no discernible threshold for several health effects associated with absorption and that biological changes occur at levels lower than 10 μg Pb/dl blood. Given that lead is a toxin with no beneficial biological function, CASAC strongly recommends a public health goal of minimizing the lead content of blood to the extent possible through reduction of lead exposures in all media of concern. Table 2.11 shows that in 1987 the first quarter mean lead concentration exceeded the proposed revision to the NAAQS (0.5 $\mu g/m^3$) at the Silver King School monitor.

While site characteristics are in conformance with the current NAAQS for lead, other concerns are identified relative to episodic wind transport of contaminated solids. These additional concerns are presented and discussed in terms of contaminant transport, population exposures and health risk in Sections 4, 5 and 6, respectively.

3.2.1.2 NAAQS for Particulate Matter

The primary and secondary NAAQS for particulate matter have also been established under the CAA and are provided at 40 CFR 50.6:

- Primary Standard: 150 $\mu g/m^3$, 24-hour average concentration. The standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 $\mu g/m^3$ for particulate matter measured as PM_{10} is equal to or less than one (1).

- Secondary Standard: 50 $\mu g/m^3$, annual arithmetic mean concentration. The standard is attained when the expected arithmetic mean concentration is less than or equal to 50 $\mu g/m^3$ for particulate matter measured as PM_{10}.

For purposes of determining attainment of the primary and secondary standards, particulate matter is measured in the ambient air as PM_{10} (particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers).

Site-specific data reflecting 24-hour PM_{10} total concentrations are available for Pinehurst only and are presented in Table 3.2. The data are reported through the U.S. Aerometric Information Retrieval System (AIRS). A single monitoring point was established where filter samples were collected several times a month. As Table 3.2 indicates, the annual arithmetic mean for particulate matter (measured as PM_{10}) exceeded the standard of 50 $\mu g/m^3$ (annual arithmetic mean) in 1986 and 1987. The 24-hour average concentration of particulate matter (measured as PM_{10}) was exceeded in 1986, 1987 and 1988 (frequency of exceedance was 9.3%, 10.2% and 2.9%, respectively). Exceedances were observed in Pinehurst during the winter months, which is a period of high usage of domestic wood burning heaters. The NAAQS were not exceeded in 1989 (prior to June) in Pinehurst.

Two PM_{10} monitors were operated 8 hours per day during high wind event monitoring from August 7 through October 15, 1989. These monitors were located at the Silver Valley Drive-In Theatre/Truck Stop (# 5) and the Kellogg Middle School (# 7). PM_{10} data from this monitoring period is not directly applicable to the NAAQS since the monitors were operated for an 8-hour period as opposed to 24-hour daily period upon which the regulations are based. Ambient air monitoring data (PM_{10}) for the 8-hour period exceeded 150 $\mu g/m^3$ 6.2 percent and 0.0 percent of the monitoring days at monitoring locations 5 and 7, respectively.

3.2.2 Idaho Rules and Regulations for the Control of Air Pollution, IDAPA Section 16.01.1000 et seq.

The State standards established for airborne particulate matter have been identified as potential ARARs for the populated portion of the Bunker Hill site. The State air quality standards are as follows:

Table 3.2
Site-Specific Ambient Air Quality Data Compared to NAAQS
(PM_{10} Total Standards for Particulate Matter)[a]

Clean Air Act NAAQS[b]		Pinehurst, Idaho					
24-Hour Average Concentration ($\mu g/m^3$)	Annual Arithmetic Mean Concentration ($\mu g/m^3$)	Year	Number of Days Sampled	Maximum 24-Hour Measured Concentration ($\mu g/m^3$)	Annual Arithmetic Mean Concentration ($\mu g/m^3$)	Frequency of Exceedance of 24-Hour Average Concentration Standard	Months When Exceedances Occurred
150	50	1986	43 days[c]	372	62[e]	9.3%	Jan., Feb.
		1987	59 days	189	68[e]	10.2%	Jan., Feb., Oct., Dec.
		1988	102 days	183	50	2.9%	Jan., Feb.
		1989	56 days[d]	124	38	0.0%	--

(a) Data reported through AIRS 1986-1989. A single monitoring station was located in Pinehurst, Idaho.
(b) National Ambient Air Quality Standards, see 40 CFR 50.6.
(c) No data reported from July 2 through October 20, 1986.
(d) No data reported July through December 1989.
(e) Underlined values indicate exceedance of NAAQS (annual arithmetic mean of 50 $\mu g/m^3$).

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- Primary standards: 75 $\mu g/m^3$, annual geometric mean; and 260 $\mu g/m^3$, maximum 24-hour concentration not to be exceeded more than once per year.
- Secondary standards: 60 $\mu g/m^3$, annual geometric mean; and 150 $\mu g/m^3$, maximum 24-hour concentration not to be exceeded more than once per year.

Airborne particulate matter is measured as total suspended particulate matter (rather than as PM_{10} on which the federal standards are currently based) for purposes of comparison to the State standards. Site-specific air quality data are available for Kellogg (1987 and 1988), Smelterville (1987) and Pinehurst (1987) through AIRS (USEPA Aerometric Information Retrieval System) (USEPA, 1989i). The data in Table 2.11 indicates that the State standards were not exceeded in Kellogg and Smelterville; however, the secondary State standard for maximum 24-hour concentration of particulate matter (150 $\mu g/m^3$) was exceeded 10.8% of the days measured in Pinehurst. Exceedances were observed in the winter months during a period of high usage of domestic woodburning heaters.

3.2.3 Threshold Limit Values (TLVs) and Estimated Limit Values (ELVs)

TLVs and ELVs, while not ARARs, have been identified as to-be-considered guidances when federal and State ARARs are not available for airborne contaminants at the Bunker Hill site. Their consideration at the site is for purposes of identifying levels of airborne contaminants at which some health risk could occur.

A TLV is based on the development of a time weighted average (TWA) exposure to an airborne contaminant over an 8-hour work day or 40-hour work week. The TLVs-TWA refer to maximum airborne concentrations of substances in the work place to which nearly all workers may be repeatedly exposed day after day without apparent adverse effects. High wind event data are provided in Table 3.3 (also Table A5.7 in Appendix A) for comparison to TLVs and ELVs. High wind event monitoring was conducted from July through October for 1987 and 1989 daily between the hours of 12:00 p.m. to 8:00 p.m. (total of 8 hours/day), and thus may be used to approximate resident and worker exposures on the site during these periods. Metals concentrations were determined on filters for which TSP was greater than or equal to 150 $\mu g/m^3$. These data are evaluated in light of the protective thresholds established as TLVs for the corresponding chemicals.

ELVs are based on TLVs and reflect exposure to contaminants on a 24-hour/day basis. The calculation of an ELV does not take into consideration the additive and synergistic effects of contaminants and additional exposures from media other than air. Due to the uncertainty associated with sensitive populations and chronic exposures, an uncertainty factor of 10 has been used to derive ELVs. ELVs are not expected to be completely protective of the potential effects of exposures to contaminants; however, they do provide some indication of airborne contaminant levels at which adverse health effects could occur. Site-specific data reflecting maximum 24-hour metals concentrations are also presented in Table 3.3 for comparison to ELVs. The site data are based on 1987 ambient air lead concentrations which were measured as part of the Idaho Air Quality Monitoring Network. Metals 24-hour maximum concentrations, other than lead, for each year are estimates based on metal-to-lead ratios from alternate years.

Review of the data presented in Table 3.3 indicates that 1987 and 1989 airborne concentrations (high wind event and the 24-hour maximum) for the populated portions of the site did not exceed the corresponding TLVs or ELVs for any of the chemicals of concern. Some of the limitations inherent in the application of TLV-based thresholds to residential exposures are:

- TLVs are for 8-hour exposure periods only and may not be protective for extended exposures;

Table 3.3
Site-Specific Concentrations of Airborne Contaminants Compared to TBCs

Contaminant	TLV - TWA[a] ($\mu g/m^3$)		High Wind Event Air Metals[b] Concentrations ($\mu g/m^3$), 1987 and 1989						ELV[e] ($\mu g/m^3$)	Estimated Maximum 24-hour[f] Metals Concentrations ($\mu g/m^3$), 1987		
			Smelterville		Kellogg		Pinehurst			Smelterville	Kellogg	Pinehurst
			1987[g]	1989[h]	1987[d]	1989[i]	1987	1989				
Antimony	500	Mean	0.05	0.03	0.03-0.14	0.03-0.04	0.02	0.04	10	0.04	0.01	0.009
		Max	0.08	0.05	0.05-0.40	0.05-0.08	0.02	0.12				
Arsenic	200	Mean	0.020	0.01	0.017-0.087	0.01-0.03	0.008	0.01	5	0.05	0.02	0.007
		Max	0.089	0.03	0.131-0.625	0.02-0.06	0.014	0.03				
Cadmium	50.0	Mean	0.015	0.01	0.011-0.044	0.01-0.02	0.002	0.01	1	0.02	0.01	0.002
		Max	0.062	0.02	0.058-0.237	0.01-0.06	0.002	0.02				
Copper	fume = 200 dust = 1,000	Mean	0.17	0.13	0.07-0.20	0.13-0.35	0.20	0.14	fume = 5 dust = 20	0.19	0.16	0.193
		Max	0.49	0.26	0.17-0.76	0.32-0.71	0.44	0.29				
Lead	150	Mean	1.00	0.72	0.38-2.40	0.20-1.42	0.22	0.11	4	1.33	0.67	0.230
		Max	8.59	3.55	2.87-15.46	0.52-2.88	1.71	0.30				
Mercury	Alkyl = 10.0 Except Alkyl: vapor = 50.0 inorganic = 100		No Data		No Data	No Data	No Data		Alkyl = 0.2 Except Alkyl: vapor = 1 inorganic = 2	No Data	No Data	No Data
Zinc	ZnCl = 1,000 Zinc Oxide: fume = 5,000 dust = 10,000	Mean	2.45	2.61	2.10-3.44	2.58-4.90	1.50	4.24	ZnCl = 20 Zinc Oxide: fume = 120 dust = 200	0.66	0.37	1.014
		Max	7.42	5.10	6.15-14.09	4.03-13.38	6.79	20.41				

(a) TLV-TWA = Threshold Limit Values - Time-Weighted Average for 8-hour workday or 40-hour work week; published by ACGIH (American Conference of Government Industrial Hygienists).
(b) See Table A5.7; also see "Data Summary Report: 1987 Air Filters for the Bunker Hill CERCLA Site Populated Areas RI/FS, Final," CH2M HILL, July 9, 1990.
(c) Data represents one sampler.
(d) Data represents five samplers.
(e) ELV = Estimated Limit Values, based on TLVs and converted to reflect exposure to contaminants on a 24-hour basis. ELVs are calculated as follows:

$$ELV = TLV\ (\mu g/m^3) \times \frac{8\ hr}{24\ hr} \times \frac{5\ days}{7\ days} \times 0.10$$

(f) See Table A3.3 in Appendix A.
(g) Data from one sampler located at Silver King School.
(h) Data from one sampler located at Mine Timber Company.
(i) Data represents three samplers.

- TLVs consider only the inhalation route of exposure and do not allow for additional or multiple intake or exposure routes; and

- TLVs are not considered protective for sensitive members of a residential population, such as children, the elderly or physiologically compromised individuals.

The comprehensive human health risk assessment will, however, address multiple exposure routes, multiple contaminants with similar target organ effects, and their effects on sensitive members of the residential population.

3.3 Groundwater

3.3.1 Safe Drinking Water Act (SDWA) (Public Health Service Act) 42 U.S.C. Sections 300f et seq.; 40 CFR 141 and 40 CFR 143.

The SDWA, and the drinking water standards and criteria established pursuant to the Act, have been identified as potential ARARs with respect to groundwater at the Bunker Hill site (see Section 6 of the PD). The primary drinking water standards include both Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs). MCLs are the enforceable standards under the SDWA. In addition to health considerations, an MCL is required to reflect the technical and economic feasibility of removing the contaminant from the water supply. MCLGs, on the other hand, are strictly health-based standards, and do not take cost or feasibility into account. They are generally more stringent than MCLs and may be applied in appropriate circumstances, such as where multiple contaminants or multiple pathways of exposure present additional risk.

Secondary MCLs (SMCLs) have been established for specific contaminants or water characteristics that may affect the aesthetic qualities of drinking water (i.e., color, odor, and taste). SMCLs are generally not health-based standards.

Site-specific data reflecting concentrations of contaminants in the groundwater at Bunker Hill are found in several RI/FS reports:

Data Report Bunker Hill RI/FS, Tasks 6.0 & 7.0: Surface Water Sampling No. 1 and Tasks 3.0, 6.0, 7.0 & 8.0: Groundwater Sampling No. 1 (Document No. 15852-PD089), Dames & Moore. June 30, 1988.

Data Report Bunker Hill RI/FS, Tasks 6.0 & 7.0: Surface Water Sampling No. 2 and Tasks 3.0, 6.0, 7.0 & 8.0: Groundwater Sampling No. 2 (Document No. 15852-PD108), Dames & Moore. October 21, 1988.

Data Report Bunker Hill RI/FS, Tasks 6.0 & 7.0: Surface Water Sampling No. 3 and Tasks 3.0, 6.0, 7.0 & 8.0: Groundwater Sampling No. 3 (Document No. 15852-PD146), Dames & Moore. February 23, 1989.

Data Report Bunker Hill RI/FS, Tasks 6.0 & 7.0: Surface Water Sampling No. 4 and Tasks 3.0, 6.0, 7.0 & 8.0: Groundwater Sampling No. 4 (Document No. 15852-PD162), Dames & Moore. May 16, 1989.

The RI/FS data for metals concentrations in the groundwater are incomplete. Groundwater data in the above reports and summarized in Table 3.4 are representative of dissolved concentrations only. The groundwater samples were filtered in the field through a 0.45 micron (micrometer) filter prior to analysis. Limited groundwater monitoring has provided a data set for comparison of both dissolved and total metals concentrations in discrete water samples (Pintlar, 1990). In general, total (dissolved portion plus suspended solid component) concentrations are similar to dissolved levels. Antimony and cadmium results seem to be consistent for the limited data available; that is, dissolved concentrations are approximate to total. Arsenic, lead, mercury and zinc (for levels > 80 mg Zn/L) show significant contributions in the suspended solid fraction. Measurement and reporting of dissolved concentrations for arsenic, lead, mercury and zinc should not be expected to be representative of the total metal concentrations of constituents measured in non-filtered water samples; the available site-specific data (at least for As, Pb, Hg and Zn) are nonrepresentative for accurate comparison. The reported concentrations for lead and zinc in Table 3.4 (including the maximum concentrations) should be considered conservative or lower-limit estimates of the extent

Table 3.4
Site-Specific Concentrations of Groundwater Contaminants Compared to ARARs

Contaminant	Safe Drinking Water Act[a] MCL (µg/L)	Safe Drinking Water Act[a] MCLG (µg/L)	Safe Drinking Water Act[a] SMCL (µg/L)	RCRA/HWMA[b] MCL (µg/L)	Minimum Frequency of Exceedance of MCL, % Occurrence[d]	Idaho[c] MCLs for Drinking Water (µg/L)	Site-Specific Groundwater Data (µg/L)[d] Kellogg Upper Aquifer	Kellogg Lower Aquifer	Smelterville Upper Aquifer	Smelterville Lower Aquifer	Background[e] (µg/L)
Cadmium	10.0 5.0[f]	-- 5.0[f]	--	10.0	84 86	10.0	Max 141 Mean 55.0	Mean 44.0[g]	Max 393 Mean 256	Max 306 Mean 164	6.0
Lead	50.0 5.0[f]	20.0 0.0[f]	--	50.0	25 79	50.0	Max 405 Mean 148	Less than 5.0[g]	Max 273 Mean 101	Max 10.0 Mean 8.0	8.5
Zinc	--	--	5,000	--	--	--	Max 32,600 Mean 12,400	Mean 13,700[g]	Max 18,500 Mean 13,100	Max 18,800 Mean 13,170	810

(a) Safe Drinking Water Act MCLs: 40 CFR Parts 141.11-141.16
MCLGs: 40 CFR Parts 141.50-141.51
SMCLs: 40 CFR Part 143.3
(b) Resource Conservation and Recovery Act, MCLs: 40 CFR Section 264.94. Idaho Hazardous Waste Management Act.
(c) Idaho MCLs for Drinking Water: Idaho Water Quality Standard, and Wastewater Treatment Requirements, IDAPA 16.01 2250,06.
(d) Data Reports for Bunker Hill RI/FS, Dames and Moore. Document Nos. 15852-PD089 (June 30, 1988), 15852-PD108 (October 21, 1988), 15852-PD146 (February 23, 1989) and 15852-PD162 (May 16, 1989).
(e) Parliman et al., 1980.
(f) Proposed Values: See 53 Fed. Reg. 31516 (August 18, 1988) for proposed values for lead; see 54 Fed. Reg 22062 (May 22, 1989) for proposed values for cadmium.
(g) Only one well representing the lower aquifer at Kellogg was sampled.

Note: Site-specific groundwater contaminant concentrations are for dissolved species and not total recoverable. The standards are based on total metals concentrations.

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and degree of groundwater contamination on the populated portions of the Bunker Hill site. Reported cadmium levels in Table 3.4 may be representative of total concentrations.

In Table 3.4, the site-specific data are compared to MCLs, MCLGs, and SMCLs (where available) for those metals for which the data indicates a need for concern (e.g., for which the standards are exceeded). There are generally two aquifers on the site, an upper and a lower, and the data are presented accordingly. The concentration of dissolved cadmium in both aquifers exceeds the current MCL and MCLG at 84% of the wells sampled in the Populated Areas. The concentration of dissolved lead is greater than the current MCL at 25% and greater than the MCLG at 44% of the wells sampled. The concentration of dissolved lead is greater than the current MCL at 25% and greater than the MCLG at 44% of the wells sampled from both aquifers. While dissolved lead in the lower aquifer does not exceed the current lead MCL, greater than 50% of the wells in the lower aquifer in Smelterville exceed the proposed lead MCL of 5 μg/L. Dissolved zinc is also present in both the upper and lower aquifer in excessive concentrations, but no MCL or MCLG has been promulgated for zinc. Dissolved zinc concentrations at 78% of the wells sampled exceed the SMCL.

It should also be noted that metals concentrations (As, Cd, Hg, Pb and Zn) in both aquifers on the site exceed background levels for the corresponding metals (see Table A5.6 in Appendix A). The information presented in Table 3.4 suggests that cadmium, lead and zinc are present in groundwater at concentrations that may pose a risk to human health if consumed. The limitations inherent in the available groundwater data should be factored into the evaluation of this risk; the data should be viewed as lower limits to total metals concentrations in groundwater at the site.

3.3.2 Resource Conservation and Recovery Act (RCRA) (Solid Waste Disposal Act of 1965; as amended by the Resource Recovery Act of 1970) 42 U.S.C. 6901; Groundwater Protection Standards, 40 CFR 264.94.

Table 3.4
Site-Specific Concentrations of Groundwater Contaminants Compared to ARARs

	Safe Drinking Water Act[a]			RCRA/HWMA[b]			Site-Specific Groundwater Data (μg/L)[d]				
Contaminant	MCL (μg/L)	MCLG (μg/L)	SMCL (μg/L)	MCL (μg/L)	Minimum Frequency of Exceedance of MCL, % Occurrence[d]	Idaho[c] MCLs for Drinking Water (μg/L)	Kellogg Upper Aquifer	Kellogg Lower Aquifer	Smelterville Upper Aquifer	Smelterville Lower Aquifer	Background[e] (μg/L)
Cadmium	10.0	--	--	10.0	84	10.0	Max 141		Max 393	Max 306	6.0
	5.0[f]	5.0[f]			86		Mean 55.0	Mean 44.0[g]	Mean 256	Mean 164	
Lead	50.0	20.0	--	50.0	25	50.0	Max 405		Max 273	Max 10.0	8.5
	5.0[f]	0.0[f]			79		Mean 148	Less than 5.0[g]	Mean 101	Mean 8.0	
Zinc	--	--	5,000	--	--	--	Max 32,600		Max 18,500	Max 18,800	810
							Mean 12,400	Mean 13,700[g]	Mean 13,100	Mean 13,170	

(a) Safe Drinking Water Act MCLs: 40 CFR Parts 141.11-141.16
MCLGs: 40 CFR Parts 141.50-141.51
SMCLs: 40 CFR Part 143.3
(b) Resource Conservation and Recovery Act, MCLs: 40 CFR Section 264.94. Idaho Hazardous Waste Management Act.
(c) Idaho MCLs for Drinking Water: Idaho Water Quality Standard, and Wastewater Treatment Requirements, IDAPA 16.01 2250,06.
(d) Data Reports for Bunker Hill RI/FS, Dames and Moore. Document Nos. 15852-PD089 (June 30, 1988), 15852-PD108 (October 21, 1988), 15852-PD146 (February 23, 1989) and 15852-PD162 (May 16, 1989).
(e) Parliman et al., 1980.
(f) Proposed Values: See 53 Fed. Reg. 31516 (August 18, 1988) for proposed values for lead; see 54 Fed. Reg 22062 (May 22, 1989) for proposed values for cadmium.
(g) Only one well representing the lower aquifer at Kellogg was sampled.

Note: Site-specific groundwater contaminant concentrations are for dissolved species and not total recoverable. The standards are based on total metals concentrations.

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and degree of groundwater contamination on the populated portions of the Bunker Hill site. Reported cadmium levels in Table 3.4 may be representative of total concentrations.

In Table 3.4, the site-specific data are compared to MCLs, MCLGs, and SMCLs (where available) for those metals for which the data indicates a need for concern (e.g., for which the standards are exceeded). There are generally two aquifers on the site, an upper and a lower, and the data are presented accordingly. The concentration of dissolved cadmium in both aquifers exceeds the current MCL and MCLG at 84% of the wells sampled in the Populated Areas. The concentration of dissolved lead is greater than the current MCL at 25% and greater than the MCLG at 44% of the wells sampled. The concentration of dissolved lead is greater than the current MCL at 25% and greater than the MCLG at 44% of the wells sampled from both aquifers. While dissolved lead in the lower aquifer does not exceed the current lead MCL, greater than 50% of the wells in the lower aquifer in Smelterville exceed the proposed lead MCL of 5 $\mu g/L$. Dissolved zinc is also present in both the upper and lower aquifer in excessive concentrations, but no MCL or MCLG has been promulgated for zinc. Dissolved zinc concentrations at 78% of the wells sampled exceed the SMCL.

It should also be noted that metals concentrations (As, Cd, Hg, Pb and Zn) in both aquifers on the site exceed background levels for the corresponding metals (see Table A5.6 in Appendix A). The information presented in Table 3.4 suggests that cadmium, lead and zinc are present in groundwater at concentrations that may pose a risk to human health if consumed. The limitations inherent in the available groundwater data should be factored into the evaluation of this risk; the data should be viewed as lower limits to total metals concentrations in groundwater at the site.

3.3.2 Resource Conservation and Recovery Act (RCRA) (Solid Waste Disposal Act of 1965; as amended by the Resource Recovery Act of 1970) 42 U.S.C. 6901; Groundwater Protection Standards, 40 CFR 264.94.

Idaho Hazardous Waste Management Act (HWMA) 39-4401 through 39-4432; IDAPA Section 16.01.5008.

The groundwater protection standards established pursuant to RCRA and HWMA have been identified as potential ARARs with respect to groundwater at the Bunker Hill site. These standards are set for groundwaters at hazardous waste land disposal facilities. The RCRA and HWMA MCLs are criteria for groundwater which is, or potentially can be, a source of drinking water. The RCRA and HWMA MCLs are equal to the SDWA MCLs for the site contaminants of concern and are identified in Table 3.4.

3.3.3 Idaho Water Quality Standards and Wastewater Treatment Requirements, Idaho Code, Title 1, Chapter 2; IDAPA 16.01.2000 et seq. (Enacted 1980; latest revision March 1988); Water Quality Standards for Domestic Water Supply (IDAPA 16.01.2250,06).

The State of Idaho's water quality standards for domestic water supply are potential ARARs for the groundwater at the Bunker Hill site. The State standards are equal to the SDWA MCLs for the site contaminants of concern and are included in Table 3.4.

3.4 Surface Water

Several laws have been identified as ARARs with regards to surface water for the populated portions of the Bunker Hill site (see Section 6 of the PD); however, exposure to surface water contaminants has not been identified as a significant exposure pathway to the typical resident. The typical resident does not engage in surface water recreational activities on site and the source of the public drinking water supply is located off-site. The public water supply has been sampled and analyzed and determined to meet federal and State water quality standards. The current drinking water supply is evaluated as part of the dietary intake in the site risk assessment. Surface water contamination at the site will be evaluated and compared to the pertinent ARARs and TBCs as part of the risk assessment conducted for the Non-populated Areas.

3.5 Blood Lead Levels

An evaluation of representative blood lead levels for children of the Bunker Hill site, in consideration of the appropriate health-based guidances and criteria, is presented here to further assess the risk posed to human health by site contamination. The following are considered in this regard:

- Centers for Disease Control (CDC) Soil/Dust Lead-Contamination Advisory, Preventing Lead Poisoning in Young Children: A Statement from the Centers for Disease Control. Atlanta. U.S. Dept. of Health and Human Services, January 1985.

- Agency for Toxic Substances and Disease Registry (ATSDR) Report to Congress, The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress. ATSDR, Public Health Service, U.S. Dept. of Health and Human Services, July 1988.

- USEPA's Review of the NAAQS for Lead, Review of the National Ambient Air Quality Standards for Lead: Assessment of Scientific and Technical Information. USEPA. March 1989.

- USEPA's Proposed Rule for Lead in Drinking Water, 53 CFR 31516 (August 18, 1988).

- USEPA's Clean Air Scientific Advisory Committee (CASAC) Report, Report of the CASAC On Its Review of the OAQPS Lead Staff Paper and the ECAO Air Quality Criteria Document Supplement. EPA-SAB-CASAC-90-002, January 1990.

CDC's Health Advisory for Blood Lead Levels states that "a blood lead level in children of 25 μg/dl or above indicates excessive lead absorption and constitutes grounds for medical intervention." This advisory level, however, may be superseded for the protection of public health due to recent information indicating adverse health effects associated with blood lead levels at 10 to 15 μg/dl, or possibly lower. As a result, CDC has indicated that consideration is being given for identifying 10 μg/dl as a community action level and 15 μg/dl as the level requiring child placement in a follow-up health program (USEPA, 1990b). Both the USEPA and ATSDR have published recent documents (see references cited above) which conclude that adverse health effects are associated with blood lead levels as low as 10 μg/dl, with no apparent threshold. CASAC (USEPA, 1990a) has also indicated that health effects associated with blood lead levels above 10 μg Pb/dl in sensitive populations clearly warrant concern. The value of 10 μg/dl refers to the maximum blood lead permissible for all members of sensitive groups, and not population mean or median values. CASAC recognizes that there is no discernible threshold for several health effects associated with lead absorption and that biological changes can occur at levels lower than 10 μg Pb/dl blood. Given that lead is a toxin with no beneficial biological function, CASAC strongly recommends a public health goal of minimizing the lead content of blood to the extent possible through reduction of lead exposures in all media of concern.

The blood lead levels reported for children at the site are discussed in detail in the PD (see Sections 3 and 5). In 1989, 275 children (ages 9 years and younger) from Smelterville, Kellogg, Page and Wardner were monitored in an areawide health survey. Of the children tested, approximately 3% exhibited blood lead levels at or above the 25 μg/dl CDC (medical intervention) advisory level. Approximately 26% of the children exhibited blood lead levels greater than or equal to 15 μg/dl; 56% exhibited blood lead levels which were greater than or equal to 10 μg/dl. In 1989, the median (50th percentile) childhood blood lead level was 10 μg/dl. The 90th percentile level for the study was 18 μg/dl and the highest blood lead level among those tested was 41 μg/dl. In 1990, 255 children were tested for blood lead in the same communities. Two (2) children exhibited blood lead levels greater than or equal to 25 μg/dl. Forty percent (40%) had levels greater than or equal to 10 μg/dl and 14% were greater than or equal to 15 μg/dl. The most recent health survey conducted in 1990 also included 107 children from Pinehurst. Approximately 11% of the children exhibited blood lead levels greater than or equal to 15 μg/dl; and 37% exhibited blood lead levels which were greater than or equal to 10μg/dl. The median childhood blood lead level was 8 μg/dl. Survey results for the population excluding Pinehurst (representing the same population group as in 1988 and 1989) showed generally lower blood lead levels than in preceding years; approximately

1% of the population exhibited blood lead levels $\geq$ 25 µg/dl, 15% $\geq$ 15 µg/dl, and approximately 40% $\geq$ 10 µg/dl. The highest blood lead level among those tested was found in Smelterville at 30 µg/dl. The lowest community mean blood lead level was found in Pinehurst at 6.7 µg/dl (median = 6 µg/dl).

BOIT790/05251-pc/jmc

4.0 CONTAMINANT FATE AND TRANSPORT

4.1 Migration Routes

Several past, present and potential routes of contaminant migration have been identified in Remedial Investigation (RI) and Risk Assessment activities at the Bunker Hill site. These migration routes occur in several media and vary in scale from phase transfers at media interfaces to meso-scale transport of airborne pollutants and surface water contaminants across the site and beyond the boundaries. The significance of the individual migration pathways depends on a number of factors. Among the important considerations are:

- The specific contaminants and concentrations involved,
- The physical and chemical characteristics of the transport media,
- The frequency and magnitude of the transport phenomena,
- The characteristics of the human and ecological receptors, and
- The persistence and tendency of contaminants to accumulate in various sinks or media.

Most of the important contaminant migration pathways associated with this site have been identified and, to a varying extent, characterized in past health and environmental research efforts. Those studies available at the beginning of the Remedial Investigation were reviewed by project personnel in 1985-86 and summarized in the *Site Characterization Report* (SCR) (WCC and TG, 1986).

Section IV of that document provided conceptual models of site contaminant migration based on the review of the information available at the time. Studies conducted since 1986 have confirmed the appropriateness of those data. Figures 4.1 and 4.2 are reproduced from the SCR and graphically portray the more significant air and water

Figure 4.1
CURRENT AIR PATHWAYS

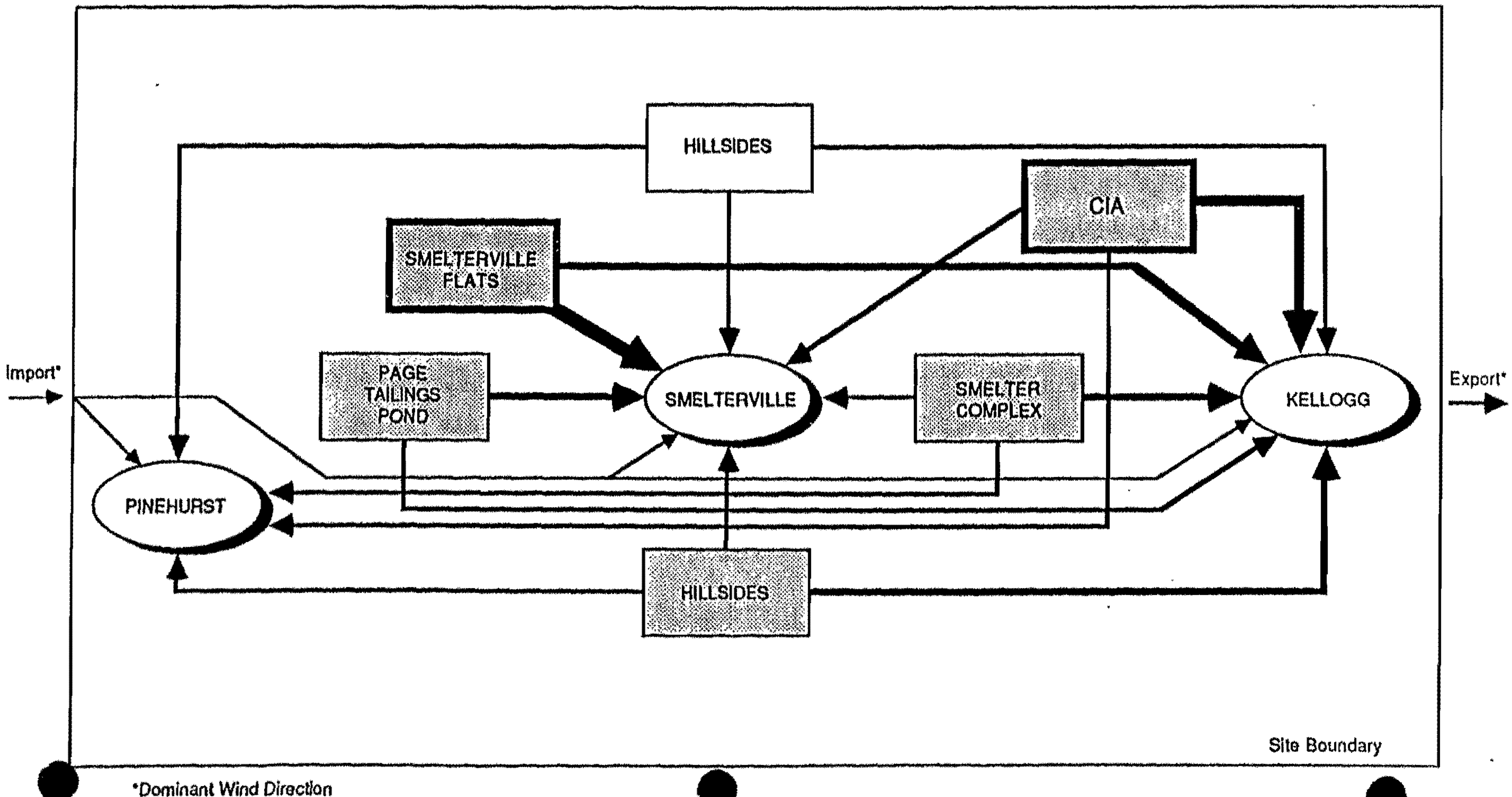
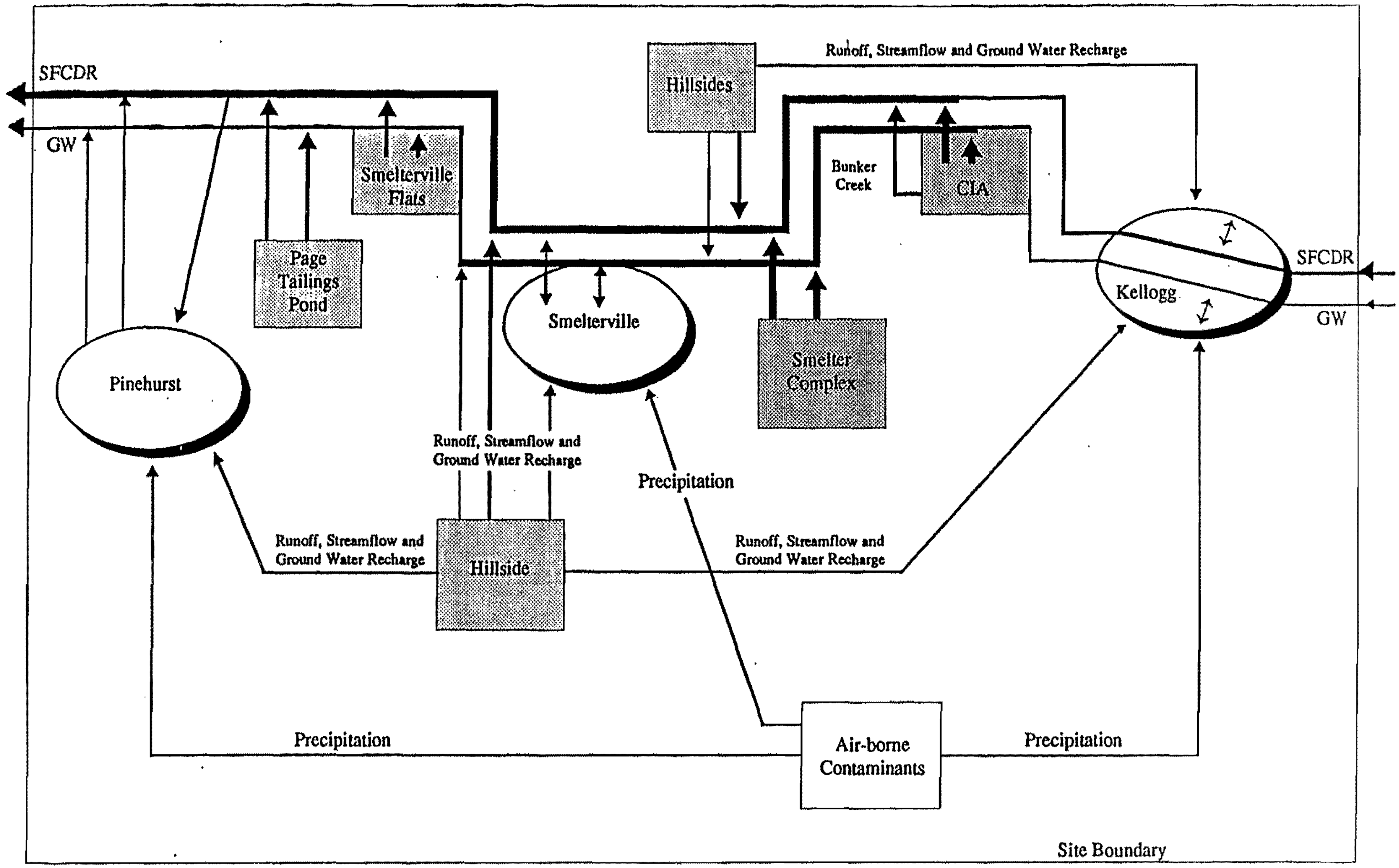


Figure 4.2
CURRENT WATER PATHWAYS



Legend -

SFCDR: South Fork Coeur d'Alene River

migration pathways, respectively. These models show the various sources and receptor areas connected by the major environmental pathways represented as arrows. The suspected significance of the respective pathways and sources are reflected by the relative "thickness" of the arrows and shading of the boxes.

These models and the underlying information were used as a basis for determining data gaps, areas where additional investigation was required, and the design of the Work Plans for both the Populated and Non-populated Areas RI/FS. There were several reasons for dividing the site into Populated and Non-populated Areas for RI/FS work. Those have been discussed in earlier site documents (WCC and TG, 1986; GRC, 1987; TG, 1990). One of the difficulties recognized in the split study design was that several contaminant migration pathways cross the RI/FS boundaries. Special consideration was given to integrating information from each effort in the task planning for both investigations. As a result, it is necessary to refer to work elements in both of the Remedial Investigations in discussing and characterizing contaminant fate and transport issues in either portion of the site.

To accommodate this project design, the contaminant fate and transport efforts in the Populated Areas Remedial Investigation and Non-populated Baseline Risk Assessment documents are coordinated efforts. This document reviews the data bases and results from both investigations and evaluates the significance of the several migration routes to the Populated Areas. This includes both contaminant transport within the Populated Areas, and transport across the boundaries from the Non-populated Areas to the Populated Areas, particularly as they affect exposure pathways to human populations. The Non-populated Areas RI/FS and Baseline Risk Assessment will focus on the role of individual sources and identified land use scenarios in effecting exposure pathways that potentially impact human health and the environment.

Because the SCR was a basic planning document for both investigations, Figures 4.1 and 4.2 are a convenient basis from which to discuss contaminant migration issues. The SCR and subsequent RI efforts have divided the important migration routes into air pathways and water pathways. These represent the predominant mechanisms by which contaminants can translocate on the site. Migration pathways, other than air and waterborne, have been noted and discussed in various documents (TG, 1986b; PHD et al., 1986; JEG et al., 1989; CH2M HILL, 1990f). Those include:

- The movement of solid-matrix wastes (both large and small volumes) in and around the deteriorating smelter complex;
- The movement of contaminated soils during construction and commercial activities;
- The tracking of contaminants from one location to another by humans, pets, vehicles, occupational activities, etc.;
- The translocation and possible bio-accumulation of contaminants in the soil profile; and
- The several pathways and physiological mechanisms associated with both external and internal exposure to the human population.

This chapter primarily focuses on those migration pathways associated with air and water transport in Sections 4.2 and 4.3, respectively. Mass movement of solid-matrix wastes and translocation of contaminants in the soil column are briefly addressed in Section 4.4. Physiological and behavioral mechanisms affecting internal and external exposures to humans and contaminant migration within the home environment are discussed in Section 5 as exposure assessment issues.

4.2 Air Pathways

4.2.1 Remedial Investigation Efforts

Several efforts in both RI/FS have been undertaken to characterize and quantify past and current airborne contaminant pathways in the project area. The results of those studies were presented in Section 2. Table 4.1 summarizes those efforts and data sources that were used in assessing contaminant migration in the Populated Areas. Both ambient air quality and emission sources were routinely monitored throughout the 1970s and 1980s. Most of these efforts were associated with past smelter operations. These data were extensively analyzed in several studies and comprehensively summarized and presented in JEG et al., 1989. Because the relative significance of various air contaminant sources has changed markedly in the post-smelter era, these historical data are not discussed in this section. Past emissions and atmospheric exposures are addressed as historical risk assessment, rather than contaminant fate and transport issues, in this document.

Table 4.1
REMEDIAL INVESTIGATION EFFORTS USED IN CHARACTERIZING CONTAMINANT MIGRATION IN THE POPULATED AREAS

Effort	Source	Results Summarized in Section
Atmospheric Monitoring		
NAAQS TSP/Pb Monitoring	USEPA, 1989i	2.2.1.1
TSP Event Monitoring - 1987	CH2M HILL, 1990e	2.2.1.2
TSP Event Monitoring - 1989	IDHW, 1990a	2.2.1.2
TSP/Deposition Monitoring - 1988	D & M, 1990c	2.2.2
Meteorological Station Summary - 1987	CH2M HILL, 1990e	2.2.3
Meteorological Station Summary - 1988	D & M, 1990c	2.2.3
Meteorological Station Summary - 1989	IDHW, 1990a	2.2.3
Meteorological Record Analysis	D & M, 1989d	2.2.3
Fugitive Dust Source Sampling		
Populated Areas Fugitive Dust Survey - 1986	TG, 1986d & CH2M HILL, 1990b	2.1.4
Non-populated Areas Dust Source Inventory - 1988	D & M, 1990a	2.1.4
Roadside Soils Survey - 1989	CH2M HILL, 1990d	2.1.3
Emission Inventory Estimates		
1986 IRM Sites Recontamination Estimates	TG, 1986a	4.2.2
Non-populated Areas Fugitive Dust Emissions Estimates	D & M, 1990a	4.2.3
Recontamination Monitoring		
1986 IRM Sites Recontamination Estimates	TG, 1986a	2.1.4
1988 Resampling of IRM Areas	D & M, 1989a	2.1.1
1989 Resampling of IRM Areas	CH2M HILL, 1990d	2.1.1
Erosion Studies		
Erosion Potential	D & M, 1990b	4.3.2
Water Quality Studies		
Surface Water/Sediment Investigation	D & M, 1988a & b	4.3.2
Groundwater Investigation	D & M, 1989b & c	3.3.1

After smelter closure, air contaminant investigation efforts have focused on fugitive dust sources. The fugitive dust source inventory for the site was updated in 1986 and concurrent fugitive dust source, ambient air and solids deposition have been collected in several RI efforts since. These studies were conducted in both the Populated and Non-populated Areas RI. As discussed in Section 2.3, the Populated Areas effort focused on sources within or adjacent to residential portions of the site and the potential public health impacts. The Non-populated Areas efforts were pursuant to a comprehensive strategy developed to address airborne contaminant transport problems in the RI/FS Work Plan negotiated with the PRP. This latter task had three primary objectives that have largely been completed. Those objectives were to:

- Define the recent ambient air quality of the project area relative to the contaminants of concern, using previously collected air monitor samples,
- Evaluate recontamination of sites within the project area by windblown dust, and
- Prepare an inventory of potential sources of fugitive dust emissions for an RI/FS.

The latter information will be used in dispersion and deposition modeling in Non-populated Areas RI/FS work to identify and rank sources for remedial measures.

Pursuant to these objectives, and in addition to the recontamination and fugitive dust source investigations noted above, several Non-populated Areas tasks were undertaken to characterize airborne contaminant pathways. These have included a comprehensive examination of wind and atmospheric stability frequencies at the site and the Spokane International Airport, and both Total Suspended Particulate (TSP) metals and solids deposition monitoring at two locations. Results of some of these studies were presented in Section 2.2. Other results pertinent to specific analyses are introduced below.

The Non-populated Areas' work complements the fugitive dust source sampling and characterization efforts in the Populated Areas RI and the State DEQ's air contaminant and weather monitoring. Collectively, these investigations were designed to evaluate the airborne exposures and atmospheric transport issues as they specifically affect the populated portions of the site. These data provide the basis for evaluating the more significant airborne contaminant migration routes at the site for both RI's and baseline Risk Assessment activities.

4.2.2 Ambient Monitoring Analyses

4.2.2.1 1987 Event Monitoring Period

Examination of TSP and metals loadings patterns from the event monitoring network presented in Section 2.2.2 shows that the majority of atmospheric dusts captured in the 12:00 noon to 8:00 pm sampling period occurs in a, relatively, few days. Nineteen peak loading days accounted for 43% of the total TSP captured from June through November, 1987. One particular day accounted for nearly 10% of total loadings. Table 4.2 shows those days ranked by mean TSP loading at the nine monitor locations.

The meteorology associated with these days shows some distinct patterns. The five days with the greatest TSP concentration in Table 4.2 account for more than 25% of the seasonal loading of TSP. Each of these days shows extreme concentrations (>250 $\mu g/m^3$) at all nine monitor locations throughout the study area. The meteorology exhibits dry surface conditions and high wind speeds from the W, WNW, and WSW directions (250-300°). Maximum hourly wind speeds for these days range from 8 to 18 mph with the 8-hour sampling period showing mean wind speeds consistently out of the west of 5.6 to 13.2 mph.

Three of the next five highest TSP days exhibit the same pattern. All monitoring locations showed high concentrations (>100 $\mu g/m^3$) and the meteorology combined dry surface conditions with high winds out of the western sectors, although wind speeds were not as severe as the preceding 5-highest TSP days exhibited. These eight days were likely affected by frontal conditions that result in extreme wind speeds, persistence, and particulate loadings throughout the region. Together these eight days account for nearly one-third of the total seasonal TSP loading for the nine sites combined. The remaining days in this group are from the period of October 27-30, 1987. These four days appear in Table 4.2 as having at least one monitor exceeding 150 $\mu g/m^3$. However, none of these days exhibited characteristically high wind speeds and high TSP readings were limited to particular monitor locations. Typical hourly average wind speeds during the sampling period were less than 3 mph. Notably lower TSP loadings were observed at locations #6 and #7, the Kellogg Middle School and Visitor's Center.

Table 4.2

AGGREGATED EXTREME TSP OBSERVATIONS AND METEOROLOGY
12 Noon to 8 PM Sampling Period
July - November, 1987

Rank	Date	Mean TSP All Sites ($\mu g/m^3$)	% Seasonal Total	Cum. % Seasonal Total	Mean Pb ($\mu g/m^3$)	Mean Cd ($\mu g/m^3$)	Mean Wind Speed mph	Mean Wind Direction 0=N	Meteorological Characteristics
1	02-Sep-87	777.3	9.8	9.8	4.52	0.058	11.7	218.4	5 hrs >10 mph from 223-267°
2	25-Oct-87	364.2	4.5	14.2	0.22	0.000	5.6	250.9	6 hrs >5 mph from 246-302°
3	15-Jul-87	346.2	4.2	18.5	1.01	0.020	13.2	250.1	6 hrs >12 mph from 244-263°
4	25-Sep-87	328.9	4.0	22.5	0.44	0.001	6.9	237.6	5 hrs >7 mph from 244-270°
5	03-Oct-87	294.2	3.6	26.1	0.27	0.002	9.2	272.3	5 hrs >10 mph from 260-287°
6	04-Aug-87	188.9	2.1	28.3	2.17	0.020	10.6	262.8	6 hrs >9 mph from 254-281°
7	28-Oct-87	185.7	2.3	30.4	1.98	0.001	1.5	213.7	all hrs <2.4 mph from various directions
8	28-Aug-87	136.7	1.7	32.1	0.61	0.010	8.9	241.2	5 hrs >10 mph from 256-279°
9	07-Oct-87	131.7	1.6	33.7	0.54	0.003	3.2	217.2	4 hrs >3 mph from 229-276°
10	26-Sep-87	127.4	1.3	35.1	0.08	0.002	3.2	133.6	1 hr >8 mph at 291° remainder low WS varied directions
11	27-Oct-87	120.0	1.4	36.5	0.79	0.005	2.1	227.0	all hrs <2.4 mph from various directions
12	29-Oct-87	117.8	1.4	37.8	0.96	0.021	2.1	229.4	all hrs <2.4 mph from various directions
13	30-Oct-87	108.9	1.3	39.1	0.67	0.010	1.6	226.0	all hrs <2.4 mph from various directions
14	29-Jul-87	80.2	0.7	40.0	0.59	0.010	5.2	229.5	4 hrs >7 mph from 242-250°
15	23-Sep-87	78.3	0.9	40.8	0.57	0.000	3.7	211.8	5 hrs >3 mph from 231-262°
16	28-Jul-87	69.7	0.6	41.6	0.18	0.000	4.4	227.1	4 hrs >4 mph from 231-263°
17	22-Sep-87	67.8	0.8	42.3	0.44	0.000	3.8	210.3	4 hrs >4 mph from 243-253°
18	17-Jul-87	66.8	0.8	43.0	0.83	0.010	8.7	94.9	4 hrs >8 mph from 60-78°
19	17-Sep-87	56.1	0.7	43.6	0.53	0.002	4.3	217.8	4 hrs >4 mph from 252-276°

The remainder of the days shown in Table 4.2 exhibit peculiar TSP loading patterns among the several monitors and differing wind speeds and direction characteristics. The 22nd and 23rd of September showed concentrations of 100-190 $\mu g/m^3$ TSP at Pinehurst, the Drive-In Theatre/Truck Stop and Shoshone Apartments (#1, #5, and #8). Wind speeds averaged 3.8 mph out of the west for six of the eight hours in the sampling period. September 26 exhibited one hour of high wind speeds with the remainder of the day at low speeds and varying direction. Most of the monitors in the valley reported loadings between 100 and 150 $\mu g/m^3$ TSP on this day.

The 28th and 29th of July were selected because of high readings (240 $\mu g/m^3$) at the Pinehurst monitor (#1). The reason for these excursions is unknown. Similarly, September 17 showed a single high reading at the Sewage Lagoon and low readings at all other locations. These locations may have been influenced by particular events affecting sources in the vicinity of the monitors on those days.

July 17th is of interest because the meteorology on that day exhibited extremely high wind speeds from the east. This condition is rare, but can provide considerable insight to airborne contaminant transport. Hourly average wind speeds were as high as 17.8 mph with four hours greater than 10 mph. The winds originated in the 60° - 80° sector or from the east-northeast. TSP loadings for this day were not severe (averaging 67 $\mu g/m^3$). However, metals loadings were especially high at monitors downwind from the smelter complex.

Examination of the metals content of the captured dusts is especially helpful in understanding the transport processes operative at the site. Table 4.3 shows the same results as Table 2.16 with metals content presented in $\mu g/gm$ in captured solids rather than $\mu g/m^3$. These units represent the concentration of metals in the dust collected from the ambient air. This table shows considerable variation in metals content both at individual monitoring locations and geographically across the site. Generally, metals levels increased with proximity to the smelter. At the westernmost site, lead levels at

Pinehurst (#1) averaged 1,647 μg/gm. Most observations at Pinehurst were below 1,000 μg/gm, however, one individual reading exceeded 10,000 μg/gm. Lead levels at the Sewage Treatment Plant (#2) ranged from 184 to 14,406 μg/gm and averaged 3,711 μg/gm.

Table 4.3

SUMMARY OF AIR FILTER METALS CONCENTRATION DATA (μg/gm)
1987 Event Monitoring Season

	Monitor Number								
	1	2	3	4	5	6	7	8	9
Analyte: Arsenic									
Minimum	15	18	20	23	21	17	23	0	24
Average	53	124	160	133	127	133	170	265	352
Maximum	155	767	1219	381	454	286	459	2048	1563
Analyte: Cadmium									
Minimum	2.6	4.6	4.7	4.3	4.5	5.0	5.1	7.8	4.1
Average	13	29	93	45	62	74	83	94	182
Maximum	44	61	660	173	413	340	368	302	691
Analyte: Copper									
Minimum	187	213	179	137	206	141	231	370	548
Average	1411	1531	1311	804	1209	932	1900	1202	1497
Maximum	3178	4314	3218	2827	3287	3041	8605	2944	3646
Analyte: Lead									
Minimum	166	184	435	368	382	258	246	370	310
Average	1647	3711	6130	4939	5865	3727	3820	6587	10041
Maximum	10198	14406	41461	11961	21123	12318	8605	27732	37770

Mean lead levels at Silver King (#3) and the Mine Timber (#4) site, both located approximately one-quarter mile west of the smelter complex, averaged 6,130 and 4,939 μg/gm Pb respectively. Site #5, Drive-In Theatre/Truck Stop located at the east end of the Smelterville Flats averaged 5,865 μg/gm. Individual readings at these sites, #3, #4 and #5, however, were high. Six samples greater than 10,000 μg/gm and one greater than 40,000 μg/gm were observed at these monitors.

Lead concentrations were notably lower at Sites #6 and #7, the Visitor's Center and Kellogg Middle School. These sites are located to the north across the valley from the smelter complex and to the north and east of the CIA. Lead concentrations averaged 3,727 and 3,820 μg/gm, respectively. One observation greater than 10,000 μg/gm was noted at these locations.

Sites #8 and #9, Mineral Subdivision and the Shoshone Apartments, exhibited the highest lead concentrations, averaging 6,587 and 10,041 μg/gm, respectively, with several individual readings exceeding 10,000 μg/gm. These sites are located in a highly contaminated, largely barren flat area east of the CIA between the mine/mill complex and river channel.

Examination of the extreme metals concentrations in conjunction with site location and meteorology can provide additional insight to the contaminant transport processes. Table 4.4 shows extreme lead concentrations observed at each monitor with the date and characteristic meteorology for the extreme level days. The highest metals concentrations are observed on relatively few days.

The highest metals concentrations at the westernmost sites were exhibited on July 17, 1987. On that day, peak concentrations of 41,461 μg/gm were observed at the Silver King School, 11,961 at the Mine Timber Site, 11,991 at the Sewage Lagoon, and 4,800 at Pinehurst. Meteorology on this day was characterized by high wind speeds (8-17 mph) from the ENE. Examining this wind direction in relation to these monitor locations on Figure 2.6 suggests anomalous high lead values observed at the western monitoring sites are likely associated with windblown dusts from the smelter complex.

Table 4.4

DAYS OF MAXIMUM OBSERVED LEAD CONCENTRATION BY MONITOR - 1987

Station	Seasonal TSP (µg/m³)	Mean Pb (µg/m³)	Pb Conc. Maxima (µg/gm)	Date	Mean Wind Speed mph	Mean Wind Direction 0=N	Meteorological Char.
1 Pinehurst School	207	0.22	4800	07/17	8.7	94.9	4 hrs >8 mph from 60-78°
			10198	10/07	3.2	217.2	4 hrs >3 mph from 229-276°
2 SV Sewage Lagoon	203	0.70	11991	07/17	8.7	94.9	4 hrs >8 mph from 60-78°
			14406	09/17	4.3	217.8	4 hrs >4 mph from 252-276°
3 Silver King School	213	0.99	41461	07/17	8.7	94.9	4 hrs >8 mph from 60-78°
			13945	10/28	1.5	213.7	all hrs <2.4 mph from various directions
4 Mine Timber Company	220	1.08	11961	07/17	8.7	94.9	4 hrs >8 mph from 60-78°
			10041	10/27	2.1	227.0	all hrs <2.4 mph from various directions
5 Drive-In Theatre	203	1.07	21123	10/28	1.5	213.7	all hrs <2.4 mph from various directions
6 Kel. Visitors Center	147	0.38	12318	10/28	1.5	213.7	all hrs <2.4 mph from various directions
7 Kel. Middle School	173	0.65	8605	10/29	2.1	229.4	all hrs <2.4 mph from various directions
8 Mineral Subdivision	180	1.21	25726	07/29	5.2	229.5	4 hrs >7 mph from 242-250°
			27732	08/04	10.6	262.8	6 hrs >9 mph from 254-281°
9 Shoshone Apartments	188	1.83	34289	07/29	5.2	229.5	4 hrs >7 mph from 242-250°
			37770	08/04	10.6	262.8	6 hrs >9 mph from 254-281°

At the sites near the valley center, #4, #5, #6, and #7, maximum metals concentrations occurred during the week of October 26 to 30, 1987. Lead levels ranged from 8,605 µg/gm at the Middle School to 21,123 µg/gm at the Drive-in Theatre/Truck Stop. Meteorology factors for this time period consisted of light winds with low persistence. These days were also noted as heavy TSP days at two of these monitors with no apparent meteorological explanation. The high metals levels observed could be indicative of anthropogenic emission generation activities within the smelter complex or on the Smelterville Flats, although there is no information available to assess this possibility.

Extremely high concentrations in excess of 27,000 µg/gm Pb were noted at Shoshone Apartments and the Mineral Subdivision Sites (#8 and #9) on July 29, 1987, and August 4, 1987. Both of these days exhibited high wind speeds from the WSW. As seen on Figure 2.6, the extreme lead levels observed at these sites were likely impacted by smelter and/or mill/concentrator sources to the southwest on these days.

4.2.2.2 1989 Event Monitoring Period

Particulate events were less severe in both frequency and magnitude in 1989 than in 1987 or 1988. Only ten days showed TSP loadings in excess of 150 $\mu g/m^3$ in 1989 versus 19 in 1987 and 16 for the same months in 1988. These differences may to be related to meteorological conditions observed in the two years. Table 4.5 shows characteristic meteorology for the peak loading days. Comparing these results to those for 1987 shows that severe events are similarly associated with high wind speeds and persistence from the WSW. However, wind speeds are notably lower in 1989.

The highest wind speeds (10-18 mph) and dust loadings (242-683 $\mu g/m^3$) were observed on October 10. Only one day, September 8, 1989, showed high wind speeds from the east.

Table 4.5

AGGREGATED EXTREME TSP OBSERVATIONS AND METEOROLOGY
12 Noon to 8 PM Sampling Period
July - October, 1989

Rank	Date	Mean TSP All Sites ($\mu g/m^3$)	% Seasonal Total	Cum. % Seasonal Total	Mean Pb ($\mu g/m^3$)	Mean Cd ($\mu g/m^3$)	Mean Wind Speed (mph)	Mean Wind Direction (0=N)	Meteorological Char.
1	10-Oct-89	346.8	9.6	9.6	1.59	0.030	12.3	242.2	6 hrs > 10 mph from 227 - 267°
2	15-Sep-89	329.4	9.1	18.7	0.70	0.012	6.3	196.7	5 hrs > 5 mph from 209 - 276°
3	26-Sep-89	267.7	7.4	26.2	0.27	0.004	4.4	216.6	4 hrs > 5 mph from 225 - 234°
4	25-Sep-89	217.4	6.0	32.2	0.35	0.005	2.2	167.8	all hrs < 4.5 mph from various directions
5	16-Sep-89	133.2	3.7	35.9	0.31	0.007	5.1	194.9	5 hrs > 4 mph from 236 - 262°
6	29-Sep-89	106.5	3.0	38.9	0.58	0.007	3.5	175.2	4 hrs > 3 mph from 211 - 239°
7	27-Sep-89	93.0	2.6	41.5	0.39	0.005	3.7	154.8	4 hrs > 4 mph from 203 - 233°
8	28-Sep-89	89.9	2.5	44.0	0.43	0.007	3.4	165.5	5 hrs > 2.5 mph from 192 - 203°
9	13-Sep-89	87.3	2.4	46.4	0.29	0.007	4.5	179.7	4 hrs > 5 mph from 216 - 228°
10	8-Sep-89	85.1	2.4	48.7	0.79	0.009	14.4	49.9	8 hrs > 12 mph from 38 - 68°

Table 4.6 provides a summary of metals content observed in dusts captured in 1989 for four metals. The highest mean lead levels were again observed at Shoshone Apartments (#9) and Mineral Subdivision (#8) (5,369 to 5,984 $\mu g/gm$ Pb). The Middle School (#7) mean was (1,730 $\mu g/gm$) and sites in the Smelterville Flats at Mine Timber (#4) and

Drive-In Theatre/Truck Stop were 3,202 μg/gm and 2,847 μg/gm, respectively. Mean values at Pinehurst and Page Sewer Lagoons were 791 μg/gm and 1,146 μg/gm Pb, respectively. The 1989 values averaged about 45% less than those observed in 1987.

Other metals show similar decreases between the two years, but continue to demonstrate the same geographic variation observed in lead concentrations. The addition of PM_{10}, (small particle measurement devices) at the Drive-In Theatre/Truck Stop (#5), and Middle School (#7) show that on average, lead content does not vary with particle size captured, copper shows mixed results, and cadmium and arsenic show about 75% higher concentrations in the small particle fraction. The latter finding is a significant result with respect to the potential carcinogenic effects of these materials. (See Section 6.)

Table 4.6

SUMMARY OF AIR FILTER METALS CONCENTRATION DATA (μg/gm) - 1989

	Monitor Number									
	1	2	4	5	5a	7	7a	8	9	10
Analyte: Arsenic										
Minimum	14	13	17	16	22	22	23	45	39	42
Average	63	73	58	58	104	88	144	117	120	115
Maximum	146	219	126	137	267	215	422	275	169	177
Analyte: Cadmium										
Minimum	11	11	11	10	20	15	31	20	19	16
Average	52	73	38	41	94	76	130	65	89	108
Maximum	151	292	67	110	356	286	563	199	175	276
Analyte: Copper										
Minimum	392	313	246	101	129	888	304	247	596	339
Average	1042	967	951	604	740	3831	949	543	1069	789
Maximum	2264	2242	2483	1264	2582	7423	1914	1306	1740	1198
Analyte: Lead										
Minimum	214	158	500	297	261	311	230	2744	871	659
Average	791	1146	2847	3202	3477	1730	1722	5369	5824	5984
Maximum	2123	5230	10310	11218	12021	3358	4422	8532	12065	11782

Table 4.7 shows observed maximum lead concentration days for each of the monitor locations. Similar to 1987, only a few days are noted. Most prominent is September 8, 1989. This was the only high loading day in 1989 when high wind speeds were observed from the east.

As observed in 1987, high metals concentrations were noted west of the smelter complex. The effect was noted as far as Pinehurst (2,123 μg/gm Pb). September 29 was noted as having high lead concentrations at several monitors. Meteorology on this day included moderate winds from the southwest for four hours, a wind reversal, and three hours of moderate wind speeds from the east. High lead concentrations were noted at monitors throughout the site. High lead concentrations were also observed on October 10 at monitors #7, #8, and #9 when high wind speeds persisted from the southwest for the entire sampling period. These monitors are all located northeast (downwind) of the smelter complex.

All of these results suggest that the highest metals concentrations observed occur downwind from the smelter and mill/concentrator complex when wind speeds exceed 5 mph, and confirm similar observations made in 1987.

4.2.2.3 Recontamination/Deposition

Examination of the concurrent TSP and deposition solids and metals data presented in Section 2.2.2 shows that total atmospheric solids loading, solids deposition and metals are all event-related. Particular days exhibiting severe dust loadings contribute a disproportionate share of the airborne TSP, subsequent solids deposition and associated metals. Although deposition estimates may be biased low (Dames & Moore, 1990d), there is a strong relationship between atmospheric loadings measured as TSP and solids deposition. The relationship between suspended and deposited metals is even stronger.

Table 4.7

DAYS OF MAXIMUM OBSERVED LEAD CONCENTRATION BY MONITOR - 1989

Station	Seasonal TSP (ug/m3)	Mean Pb (ug/m3)	Pb Conc. Maxima (µg/gm)	Date	Mean Wind Speed (mph)	Mean Wind Direction (0=N)	Meteorological Char.
1	157	0.086	2123	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			1014	9/29	3.5	175.2	4 hrs > 3 mph from 211 - 239°
2	144	0.082	5230	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			1351	9/29	3.5	175.2	4 hrs > 3 mph from 211 - 239°
4	168	0.554	10310	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			4518	9/13	4.5	179.7	4 hrs > 5 mph from 216 - 228°
5	209	0.451	11218	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			4250	9/16	5.1	194.9	5 hrs > 4 mph from 236 - 262°
5a	110	0.269	12021	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			5110	9/16	5.1	194.9	5 hrs > 4 mph from 236 - 262°
7	129	0.201	3358	9/27	3.7	154.8	4 hrs > 4 mph from 203 - 233°
			2992	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
7a	69	0.116	4422	10/10	12.3	242.2	6 hrs > 10 mph from 227 - 267°
			2733	9/28	3.4	165.5	5 hrs > 2.5 mph from 192 - 203°
8	221	1.241	8532	10/10	12.3	242.2	6 hrs > 10 mph from 227 - 267°
			8059	9/29	3.5	175.2	4 hrs > 3 mph from 211 - 239°
9	192	1.033	12065	9/8	14.4	49.9	8 hrs > 12 mph from 38 - 68°
			8086	10/10	12.3	242.2	6 hrs > 10 mph from 227 - 267°
10	201	1.179	11782	10/10	12.3	242.2	6 hrs > 10 mph from 227 - 267°
			7915	9/29	3.5	175.2	4 hrs > 3 mph from 211 - 239°

Figures 4.3a and 4.3b show the relationship between weekly suspended lead captured in the atmosphere and lead content of deposition solids for the 1988 Dames & Moore study. An exceptionally strong and consistent relationship is observed across both sites. Figure 4.3c shows these results combined for the two sites. More than 85% of the variance in lead deposition is explained by concurrent atmospheric lead loadings. This suggests that metals loadings in the atmosphere could be an effective predictor of deposition. Deposition, in turn, seems to be indicative of potential recontamination and resultant surface dust concentrations.

Metals concentrations in the captured solids are summarized in Table 4.8. Similar to TSP and airborne metals findings, highest concentrations for these metals did not necessarily correspond with highest total solids loadings. Recontamination potential or dust, litter and surface soil metal contaminant levels can be estimated from Table 4.8. On a weekly basis, surface lead concentrations of newly deposited dust, for example, could range to the maximum observed in the collected solids, (i.e., 16,000 to 19,000 μg/gm). On an annual basis, concentrations could be as high as the weighted mean of 5,000 μg/gm at the Mine Timber Site or 2,250 μg/gm at the Middle School. These concentrations would dilute rapidly as the dust incorporates into the surface soils. The last column in Table 4.8 shows annual estimated metals deposition in mg/m^2. The value of 111.3 mg/m^2 year for Smelterville is equivalent to about one pound of lead per acre per year. If this material were to distribute uniformly through the top inch of mineral soil, the following annual increase in soils metals content might be expected throughout the top inch of soil:

$$\frac{111.3 \mu g Pb}{m^2} * \frac{1 m^3 soil}{370 gm} * \frac{39.36 in}{1 m} = 11.8 \ \mu g/gm\ Pb/year$$

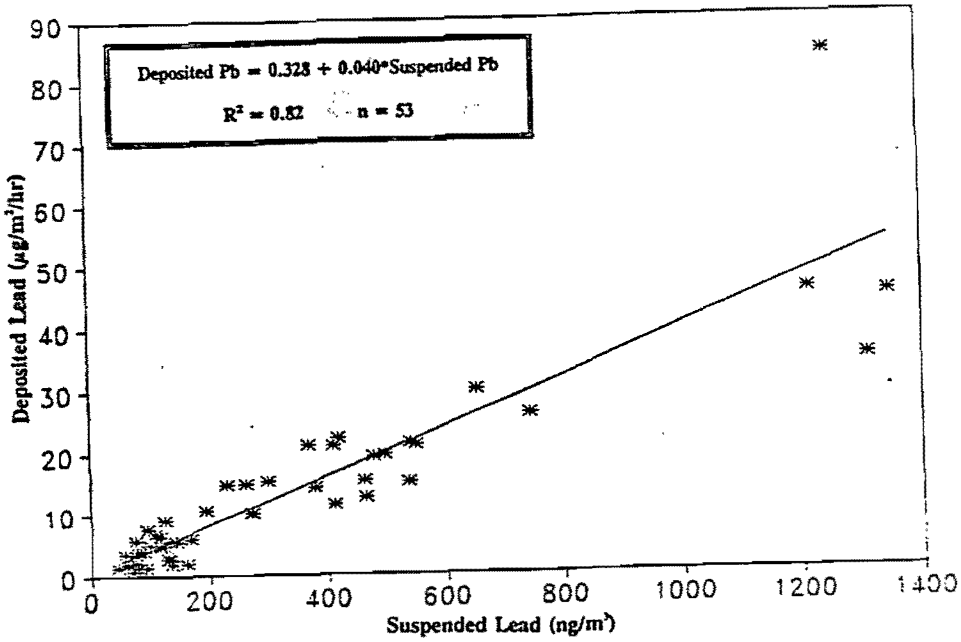


FIGURE 4.3a
Relationship Between Lead in Deposited Solids and Suspended Lead Concentrations - Smelterville

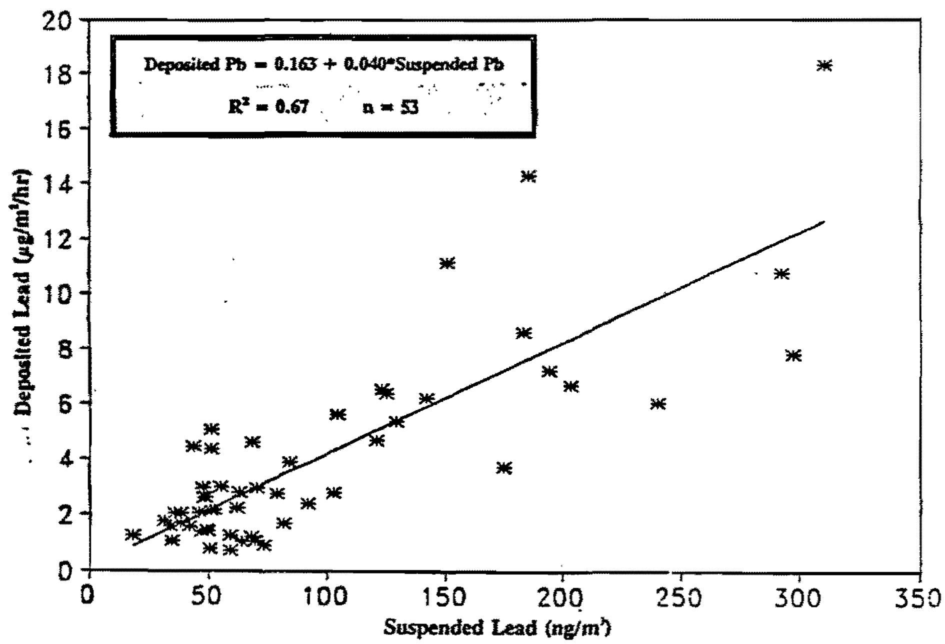


FIGURE 4.3b
Relationship Between Lead in Deposited Solids and Suspended Lead Concentrations - Kellogg

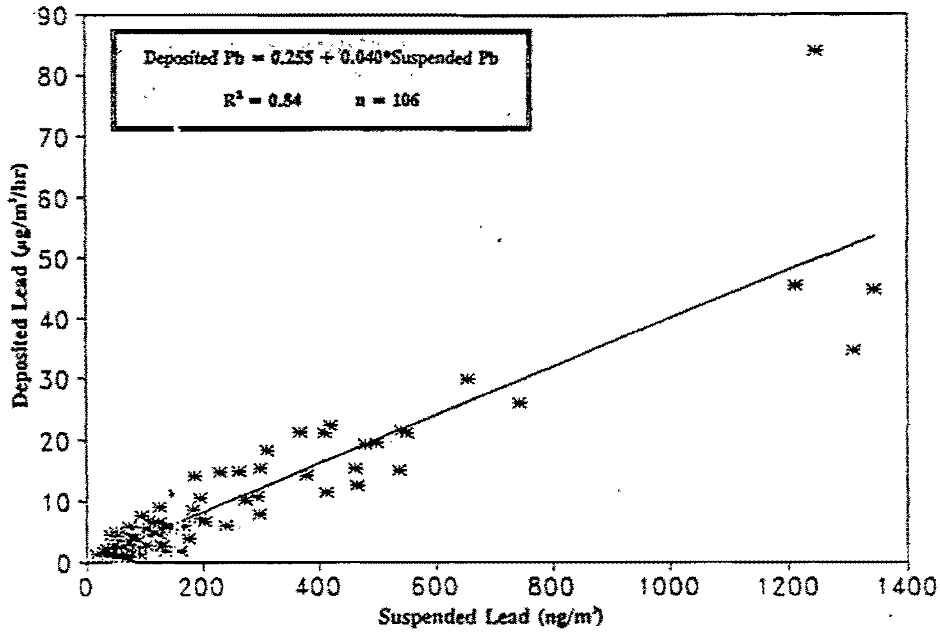


FIGURE 4.3c
Relationship Between Lead in Deposited Solids and Suspended Lead Concentrations - Combined Sites

A similar calculation for the Kellogg Middle School yields an estimated increase of 3.7 μg/gm lead per year. Estimated increases in litter layers could be an order of magnitude higher due to the lesser bulk density of the vegetative material. However, lead would not likely continue to accumulate in litter for as many years as in the ultimate sink of the mineral soil. Eventually levels in both soil and litter would likely equilibrate with the mean concentrations approximating those observed in deposited dusts (i.e., 2,250 - 5,000 μg/gm at these sites).

The lead concentration values observed in deposited solids also corresponds with that observed in the TSP at these sites for all three years of observation. Table 4.9 shows those results. Although the mean values are not directly comparable because of differences in sampling and averaging techniques, these data suggest that the lead content of solids, either suspended or deposited, is similar for the three years. This suggests that the spatial variation in particulate metals levels is likely related to sources in the immediate vicinity of individual monitors.

Table 4.8

TOTAL METALS IN DEPOSITION SOLIDS - 1988
Smelterville Mine Timber (#4)

Metal	Deposition Rate $\mu g/m^2/hr$ Mean	Range	Concentration in Total Dry Deposition Solid mg/kg Mean	Range	Total Annual Deposition mg/m^2
Pb	12.70	0.8-83.8	5015	764-16800	111.3
Cd	0.11	0.02-0.43	68	4-347	1.0
As	0.25	0.03-1.45	117	13-316	2.2
Zn	11.25	2.7-36.9	7121	1094-23508	98.6
Mn	8.60	1.1-35.0	4532	1111-11545	75.3
Fe	131.90	13.2-620.9	61762	23002-158507	1156.0
Sb	0.17	0.02-0.48	91	9-225	1.5
Cu	0.66	0.12-2.35	393	80-1162	5.7

KELLOGG MIDDLE SCHOOL (Site #7)

Metal	Deposition Rate $\mu g/m^2/hr$ Mean	Range	Concentration in Total Dry Deposition Solid mg/kg Mean	Range	Total Annual Deposition mg/m^2
Pb	3.99	0.72-18.3	2257	527-18868	35.0
Cd	0.08	0.01-0.65	69	6-538	0.7
As	0.19	0.02-1.43	127	17-352	1.7
Zn	5.65	1.6-30.5	4873	653-16791	49.5
Mn	3.65	0.65-21.8	2508	699-6063	32.0
Fe	70.70	9.6-343.3	42841	15134-91300	620.0
Sb	0.09	0.02-0.32	82	12-300	0.8
Cu	0.48	0.10-6.38	465	64-8000	412.0

Adapted from Dames & Moore, 1990c.

Table 4.9

LEAD CONTENT OF CAPTURED SOLIDS
TSP AND DEPOSITION 1987 - 1988

Mine Timber (#4) and Kellogg Middle School (#7) Sites

	Mine Timber Mean	Range	Middle School Mean	Range
*1987 TSP	4939	368-11961	3820	246-8605
1988 TSP	4492	181-11413	2300	88-2721
1988 Deposited Solids	5015	764-16804	2356	527-18868
1989 TSP	2847	500-10310	1730	311-3358

*1987/89 data are for peak event days only
1988 data are for entire year

The effect can be seen in the metals levels in captured solids during event monitoring. Table 4.3 shows the geographic variation in lead concentration to be significant, ranging from an average of 1,647 μg/gm Pb at Pinehurst to more than 10,000 μg/gm at the Shoshone Apartments. The relationship between suspended and deposited lead shown in Figure 4.3c suggests that deposition rates would also vary geographically over the site in a manner directly proportional to suspended metals concentrations. Table 4.10 shows estimated lead metals deposition rates for 1987 obtained for the other monitoring sites using the relationships illustrated in Figure 4.3c.

Table 4.10

ESTIMATED ANNUAL LEAD DEPOSITION RATES AT EVENT MONITOR LOCATIONS

Monitor Location	Mean TSP Conc. $\mu g/m^3$	Mean Pb Content of TSP	Estimated Suspended Pb ($\mu g/m^3$)	Estimated Deposited Pb ($\mu g/m^3/hr$)	Estimated Annual Lead Deposition mg/m^2	lbs/acre	Estimated Annual Increase in Top Inch Soil ($\mu g/gm$)/yr
1	87	1647	0.143	6.0	52	0.5	6
2	76	3711	0.282	11.5	100	0.9	12
3	71	6130	0.435	17.7	155	1.4	19
4	79	4939	0.390	15.9	139	1.3	17
5	71	5865	0.416	16.9	148	1.4	18
6	55	3727	0.204	8.4	74	0.7	9
7	58	3820	0.222	9.1	80	0.7	9
8	60	6587	0.395	16.0	140	1.3	17
9	70	10041	0.702	28.3	248	2.2	30

These observations agree well with the range of recontamination rates estimated for the Interim Remedial Measures (IRM) Fast-Track sites remediated in 1986 (TG, 1986a). That initial atmospheric transport investigation was conducted using fugitive dust source inventories from earlier studies (PedCo, 1975; PES, 1977; von Lindern, 1980) and applied the U.S. Department of Agriculture (USDA) wind erosion equation to estimate potential recontamination rates from windblown dust (Wilson, 1975). Based on assumed wind conditions, the effort applied a simplified Gaussian dispersion model to estimate the order of magnitude of deposition rates at the proposed remedial locations (TG, 1986a).

Maximum recontamination rates (increases in soil lead concentrations) due to deposition of windblown dust were estimated to be on the order of .2 to 5.0 pounds of lead per acre per year depending on the location of the receptor. This rate translated to estimated increases of tens to hundreds of parts per million lead per year in clean soils. These findings implied that after several years, soil could be recontaminated to levels of concern for human health. The results also indicated that the major suspected sources of wind reentrained lead particulates were the CIA, the lead smelter complex, denuded hillsides in the vicinity of the complex, and barren areas near the Kellogg Middle School. Due to the unknown validity of the source inventories used and the simple methods applied in this study of resuspension and dispersion of windblown dust, conservative (i.e., worst case) assumptions were used. As a result, it was recognized that recontamination effects may be overestimated.

Two efforts to assess recontamination rates at remediated sites were presented in Section 2.1.1. Table 2.3 showed original concentrations, remedial material concentrations, contaminant levels measured two and three years after remediation and the 1986 original recontamination estimates for the "Fast-Track" remedial sites.

These results suggest that surface recontamination rates were as expected, less than those predicted in 1986, and similar to those observed in the 1988 deposition monitoring. The few litter samples that were collected suggest recontamination rates of 10 - 100 μg/gm/yr lead. No recontamination was evident in either the top inch or middle of the soil fill on sodded sites or play fields. Some recontamination was evident at the interface of replaced soils and top of the original cut. Whether this is due to contaminant migration, mixing at the time of placement, or imprecise layering of the sample is unknown.

Graveled areas, particularly those used as parking lots, showed significant recontamination. Because of the low rates of surface deposition, these increases likely resulted from the continual working against the original layers below or tracking of contaminants by vehicles. The high levels noted on paved surfaces and the tennis court are suggestive of the high concentrations seen in the collected solids during the 1988 deposition studies and observed as suspended lead. This indicates that highly concentrated dusts from particular sources can present exposure concerns independent of the short-term recontamination potential.

More recently, deposition modeling efforts in the Non-populated Areas RI suggest that observed deposition rates may be biased low and actual recontamination rates may be higher than suggested from monitoring data (Dames & Moore, 1990d).

4.2.2.4 Summary of Ambient Particulate and Deposition Analyses

In summary, these studies suggest that airborne particulate and deposited solids are event-related. The majority of both atmospheric loadings and deposition occur on relatively few days during the year and are related to high wind speeds and dry surface conditions. Metals levels in suspended particulate and deposited solids correlate well at individual monitoring locations and geographically across the site. The latter observation supports the conclusion that metals, in both the air and deposited solids, originate from sources in the general vicinity of the monitors. As a result, both the concentration of metals in the solids and the rate of metals accumulation through deposition depend on the location and orientation of the receptor to major dust sources in the valley. The highest particulate loadings are observed downwind from large barren areas of the valley floor. The highest metals concentrations are seen downwind from the Smelter complex and mill/concentrator area.

Short-term metals concentrations in depositing dusts ranged from 1,600 to 20,000 μg/gm lead. These are high levels and warrant concern in areas accessible to young children. Long-term average concentrations could range from 1,000 to 10,000 μg/gm lead and could result in significant recontamination of remediated areas to similar levels over a period of years. The highest lead concentrations in transported dusts are observed at locations nearest the most contaminated sources. Those sources are addressed in the next subsection.

4.2.3 Fugitive Dust Source Emission/Impact Estimates

4.2.3.1 Emissions Estimates

Considerable effort has been expended in the Non-populated Areas RI to characterize fugitive dust sources throughout the site. Emissions estimates have been developed for the complete windblown dust source inventory for the site (Dames & Moore, 1990a). These results will be used to support sophisticated modeling analyses in the Non-populated Areas FS. They are presented below with simple modeling techniques to characterize these sources impacts in the Populated Areas for risk assessment purposes.

Table 2.12 and Figure 2.4 showed sampling results and locations for 17 potential wind blown dust source areas sampled in the Populated Areas RI effort in 1986. This investigation focused on suspected wind blown dust sources located on the valley floor with the greatest potential to impact residential areas. Several other fugitive dusts sources located on the hillsides or within the smelter complex were not sampled at that time.

In 1988-89, the remaining suspect fugitive dust source areas throughout the entire Study Area were sampled as part of the Non-populated RI/FS (Dames & Moore, 1990a). These results were combined with those sources characterized in the Populated Areas RI to produce an overall fugitive dust source map for the entire site using the Windblown Dust Equation methodology in a manner similar to earlier studies (PedCo, 1975; PES, 1977; von Lindern, 1980; TG, 1986a). This methodology results in an estimate of amount of dust suspended by winds from each acre of surface in an annual or seasonal period.

Appendix A4.1 shows the source area designations and summary statistics and emission estimates for each source for the entire site for total particulates and select metals. It is estimated that approximately 485 tons of particulate, 5,450 lbs. lead, 77 lbs. cadmium, and 163 lbs. arsenic are suspended annually from the 103 windblown sources identified in the study area (Dames & Moore, 1990a). Recent analyses by CH2M HILL indicates that approximately 5,321 lbs/day of particulates are suspended by traffic in the Populated Areas of the site. Assuming 180 days of dry surface conditions per year, this translates to approximately 479 tons/yr of particulate suspension from road surfaces. Assuming an area mean concentration of 1,500 ppm lead in road dust yields and annual lead suspension from roads of 1,450 lbs. (CH2M HILL, 1989; CH2M HILL, 1990g).

Figure 4.4a shows the location, with respect to the overall site and the sources identified in Appendix A4.1, of the ten largest total particulate fugitive dust sources indicated in Dames & Moore 1990a. These sources include a variety of larger areas ranging in size from 140 to 1,531 acres. Included are several barren zones on both the north and south-facing hillsides, barren areas in the vicinity of the smelter, river channel, and Smelterville industrial corridor. These sources encompass 5,735 acres or about 39% of the total site area. In total they account for approximately 226 tons/year of suspended particulate or about 47% of the estimated total windblown dust emissions for this study area.

Although these sources account for a large percentage of the total site emissions, other sources are more likely to adversely impact the Populated Areas because of proximity, per unit area emission rate factors, and metals content.

Figure 4.4b shows the ten sources with highest particulate emission rates (tons per acre per year). None of the hillside sources appear on this list. However, both the Airport (#U61) and Forest Products (#U62) areas from the Smelterville Flats, are in the top ten for both total emissions and emission rate. The other sources with highest per area particulate emission rates are in the vicinity of the CIA (#U69, U70, U71) the Mill/ Concentrator Area (#H2, U53), specific areas in the Smelter Complex (#H9, H5) and the Page Ponds Dikes (#U67).

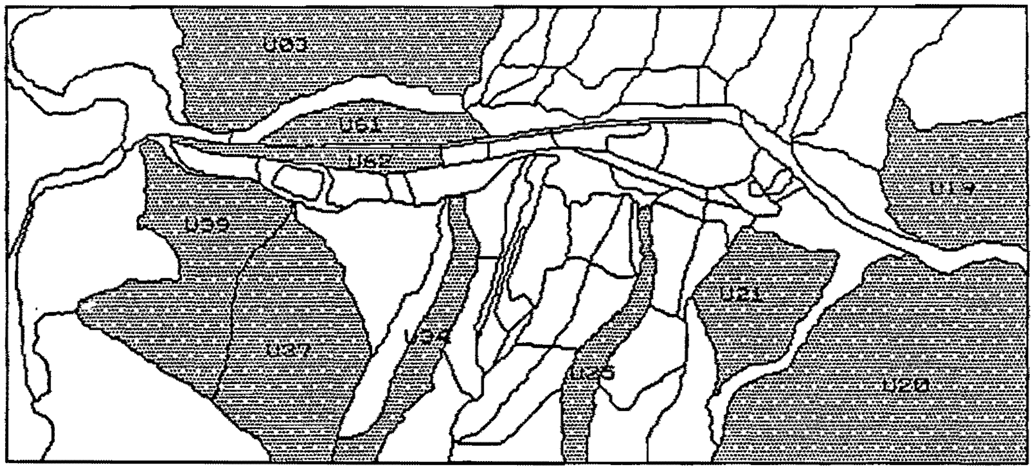


FIGURE 4.4a
Fugitive Dust Sources Ranked by Total Emissions

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/yr)	Pb - - -	Cd (lbs/yr)	As - - -
U20	SE HILLSIDE	1531	57	270	1.4	9.3
U61	AIRPORT AREA	218	35	1130	3.6	14.8
U03	N HILLSIDE	928	24	47	0.4	1.6
U37	SW HILLSIDE	807	21	30	0.4	1.4
U21	SE HILLSIDE	403	18	67	0.4	1.2
U62	FOREST PRODUCTS	140	17	580	2.1	9.0
U39	SW HILLSIDE	746	15	67	0.5	1.5
U34	S HILLSIDE	244	14	16	0.3	0.8
U19	NE HILLSIDE	523	13	56	0.3	0.9
U25	S HILLSIDE	195	12	27	0.2	0.7

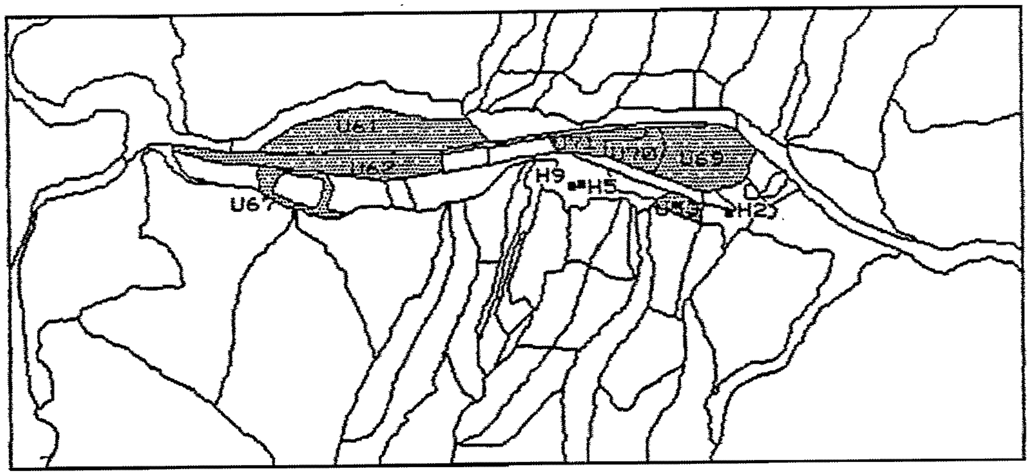


FIGURE 4.4b
Fugitive Dust Sources Ranked by Emission Rates

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/acre/yr)	Pb	Cd (lbs/acre/yr)	As
H9	WHEELABRATOR BAGHOUSE	0.014	0.18	170.4	20	58
U61	AIRPORT AREA	218	0.16	5.2	0.02	0.07
U53	OLD HOMESITES	25	0.14	6.1	0.05	0.13
H2	N OF CONC BLDG	0.092	0.13	7.9	0.15	0.20
U71	SLAG PILE	49	0.12	2.6	0.05	0.11
U67	PAGE POND DIKES	49	0.12	1.1	0.01	0.05
U62	FOREST PRODUCTS	140	0.12	4.1	0.01	0.06
U69A	CIA BEACHES	97	0.11	0.2	0.01	0.20
U70	GYPSUM POND/DIKES	56	0.11	0.5	0.01	0.04
H5	NORBLO BAGHOUSE	0.018	0.11	79.3	4.39	26

Figure 4.5a shows similar results for total lead emission sources. Unlike total particulates, the largest predicted lead sources are mostly confined to the valley floor. The Smelterville Flats areas near the Airport (#U61) and the Forest Products (#U62) areas are the two largest lead sources followed by the Smelter Complex (#U55) and Warehouse (#U51) area. These four sources account for 50% of the total estimated

wind suspended lead for the site. One hillside appears on this list, but may be an artifact resultant from the disproportionate size of this area. Also included among the ten largest total lead emission sources are several barren areas on the valley floor and within the smelter complex. These ten sources account for 67% of the sitewide total lead emissions.

Figure 4.5b shows the ten largest Pb emission rate sources by unit area. These sources are all located in or near the lead smelter complex and include areas exhibiting mean lead concentrations ranging from 61,100 to 497,000 μg/gm. These same sources also appear in Figures A4.2 through A4.5 in Appendix A4.1 as having the ten largest arsenic and cadmium emission rates. Generally, the highest emission rates for all contaminants of concern, in units of mass per area, occur in or near the smelter and are related to the high metals content of these sources.

In terms of total metals, Figures A4.2a through A4.5a in Appendix A4.1 show significant differences in those sources that contribute most to suspended arsenic and cadmium particulates from the site. The largest sources of cadmium are the lead Smelter Complex (#U55) and Warehouse (#U51) area. These two sources account for nearly 60% of total cadmium windblown emissions for the entire site. Other important sources are the Airport Area and Forest Products, the Slag Pile area, and hillsides and barren zones near the smelter complex. The ten largest sources of cadmium account for 79% of sitewide total cadmium emissions.

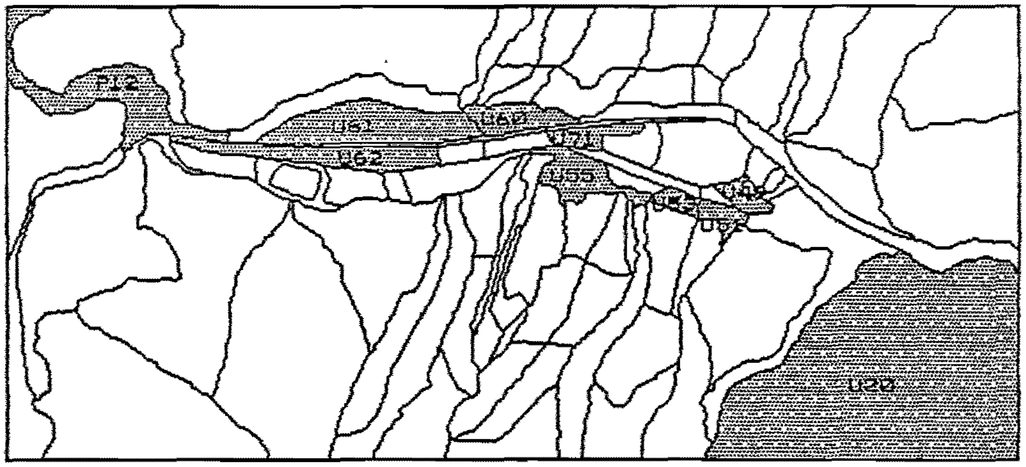


FIGURE 4.5a
Fugitive Dust Sources Ranked by Total Lead Emissions

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/acre/yr)	Pb - -	Cd (lbs/acre/yr)	As - -
U61	AIRPORT AREA	218	35.4	1130	3.6	14.8
U62	FOREST PRODUCTS	140	16.7	580	2.1	9.0
U55	PB SMELTER COMPLEX	99	1.6	552	24.2	11.5
U51	WAREHOUSE AREA	34	1.0	451	21.6	18.5
U20	SE HILLSIDE	1531	57.1	270	1.4	9.3
P12	CDA/PINE CREEK CONFLUENCE	238	7.3	160	0.0	0.0
U53	OLD HOMESITES	25	3.7	155	1.3	3.3
U71	SLAG PILE	49	5.9	127	2.3	5.5
U49	NEAR SHOSHONE APARTMENTS	31	1.3	125	0.1	0.6
U60	OUTDOOR THEATER	80	5.6	103	0.6	2.5

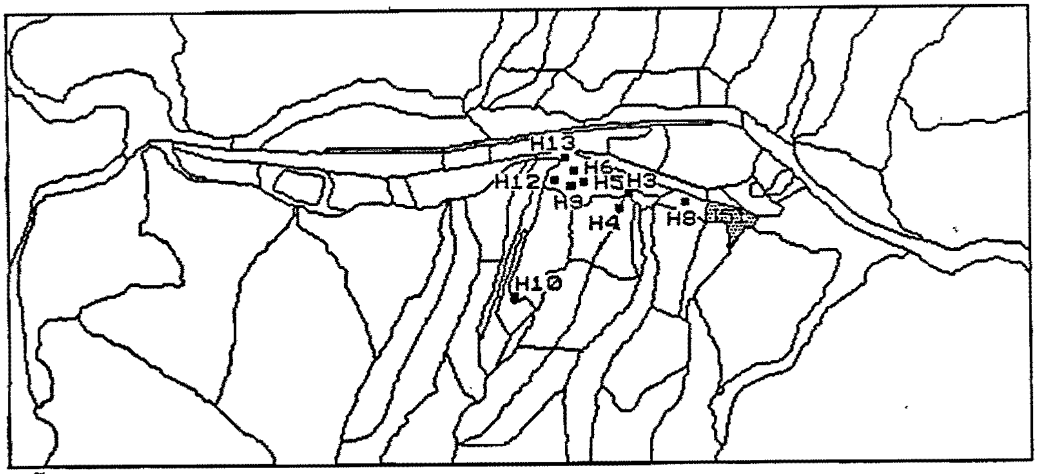


FIGURE 4.5b
Fugitive Dust Sources Ranked by Lead Emission Rate

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/acre/yr)	Pb - -	Cd (lbs/acre/yr)	As - -
H9	WHEELABRATOR BAGHOUSE	0.01	0.18	170.42	19.64	57.77
H5	NORBLO BAGHOUSE	0.02	0.11	79.27	4.39	26.14
H4	MAGNET GULCH STORAGE	0.69	0.10	76.25	2.87	20.41
H6	BLAST FURNACE AREA	0.23	0.03	33.60	0.32	1.12
H12	SWEENEY POND CLEAROUT	0.23	0.07	23.24	3.90	0.55
H10	CD PLANT TANKS	0.03	0.04	21.46	3.08	0.69
U51	WAREHOUSE AREA	33.85	0.03	13.34	0.64	0.55
H8	BOULEVARD AREA	5.52	0.07	13.24	0.12	1.98
H13	STORAGE AREA W PB SMELTER	0.69	0.02	11.51	0.31	0.36
H3	CROSBY POINT	0.11	0.08	9.98	0.25	1.83

Most of the same sources are indicated for arsenic total emissions. However, the largest single arsenic source is the CIA Beaches that were not indicated among the largest lead or cadmium source. Several of the ten largest arsenic sources have similar total emissions and together account for 71% of sitewide total suspended arsenic emissions.

The results discussed in Section 4.2.3 suggest that both atmospheric metals loadings and deposition are sensitive to local source configurations in the immediate vicinity of the monitors. This observation is further supported by examination of the relationship between suspended metals loadings and deposition and, in turn, the relationship between fugitive dust sources and metals loadings.

4.2.3.2 Impact Estimates

The simple Gaussian plume model employed in the 1986 recontamination study and discussed in the USEPA's *Superfund Exposure Assessment Manual*, (USEPA, 1988a), can be used to provide a first order evaluation of the relationship between metals loadings in TSP and local fugitive dust sources. USEPA 1988a shows the following form of the Gaussian Plume Model.

$$x = \frac{Q}{2\pi\sigma_y\sigma_z u}$$

where

Q	=	release rate of substance from site, (mass/time).
σ_y	=	dispersion coefficient in the lateral (crosswind) direction, (distance).
σ_z	=	dispersion coefficient in the vertical direction, (distance).
u	=	mean wind speed, (distance/time).
π	=	the value pi = 3.14.
x	=	atmospheric concentration (mass/volume)

Because majority of atmospheric total particulate and metals loadings at this site occurs under prescribed meteorological conditions, this model can be simply applied to identify critical sources at select monitor locations. Earlier discussions showed that most particulate events are associated with high wind speeds (5 to 20 mph) out of the west/ southwest sectors under C and D stability. Solving the Gaussian equation at representative wind speeds under C stability suggests that under these conditions the major portion of metals loadings observed at a monitor derives from sources located directly upwind and within a few thousand yards of the monitor.

Because most of the winds capable of suspending significant particulate emissions come from the W, WSW, and WNW sectors, sources located within 1-1/4 miles upwind in that direction are those most likely to contribute to the cumulative impact at the monitor location. Figure 4.6a shows these sectors extending 1-1/4 miles upwind from select monitor locations. Figure 4.6b shows the Mine Timber site in detail. The sources located within these sectors are suspected of contributing the greatest load to the monitor during major WSW wind events. The potential impact at the monitor location of the various sources included in this upwind sector can be evaluated using the Gaussian plume equation. That equation was solved for each of the source-monitor combinations to identify expected particulate metals concentrations from the inclusive sources at each monitor location.

This simplified analysis was accomplished under the following assumptions developed from the June to November 1987 meteorological observations.

- Stability Category C - Typical wind speed - 4.5 mph
- Wind direction

Wind direction	WNW	- 17% of time
	W	- 55% of time
	WSW	- 28% of time

- Emission Rates from Dames & Moore, 1990a (Appendix A4)

Table 4.11 shows those sources expected to contribute the largest TSP and lead impacts under this particular directional scenario for each monitor location. The source identification numbers correspond to those in Appendix A4, Figure A4.1 and Table A4.1. Similar analyses could be accomplished for other meteorological scenarios.

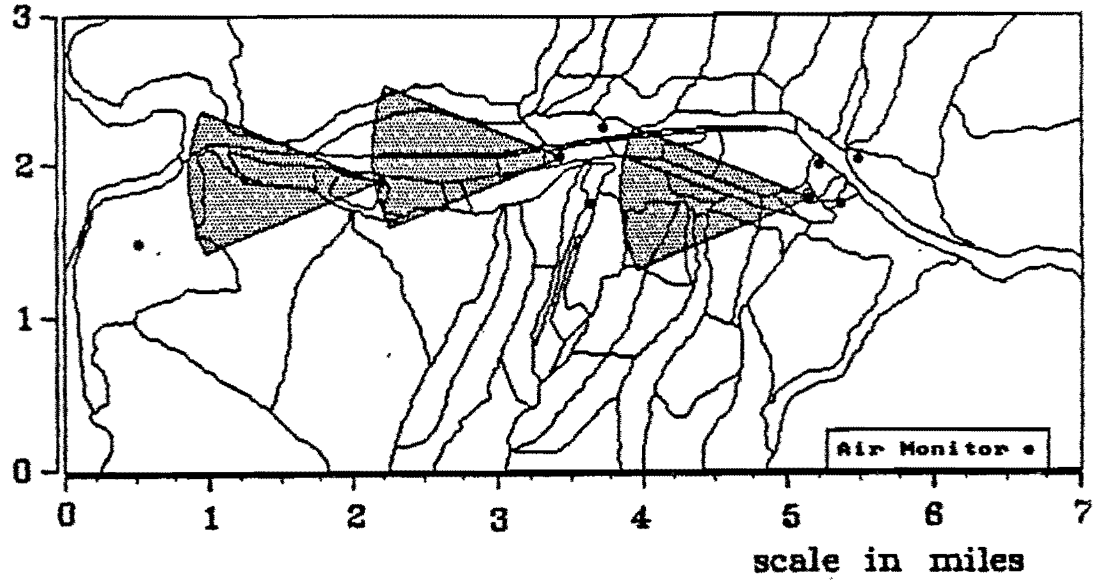


Figure 4.6a
Example Up-Wind Sectors for Select Monitor Locations

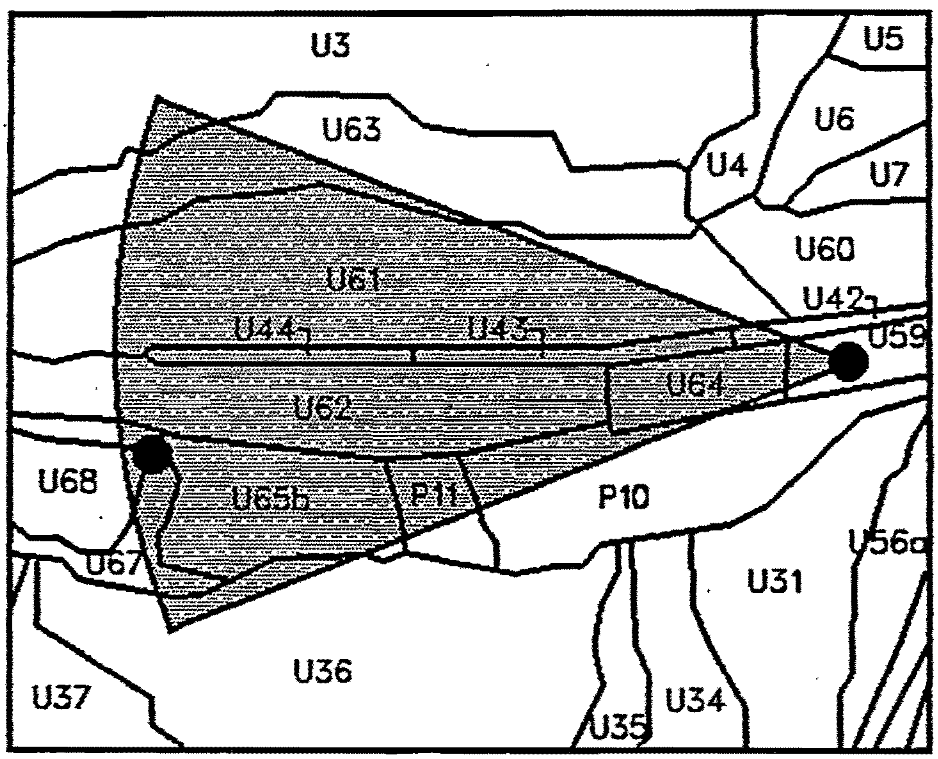


Figure 4.6b
Detailed Up-Wind Sector for Smelterville Mine Timber Site

Table 4.11

POTENTIAL MAJOR SOURCE CONTRIBUTORS TO MONITOR LOCATIONS FROM THE WNW, W, WSW WIND DIRECTIONS*

Monitor #	Description	Largest TSP Sources in WNW, W, WSW Sectors	Largest Pb Sources in WNW, W, WSW Sectors
1	Pinehurst School	P14 PINEHURST P13 PINE CR. CHANNEL U01 NW HILLSIDE	P14 PINEHURST U01 NW HILLSIDE P13 PINE CR. CHANNEL
2	Smelterville Sewage Lagoon	U67 PAGE POND DIKES U62 FOREST PRODUCTS U61 AIRPORT AREA U39 SW HILLSIDE U65A W PAGE SWAMP	U62 FOREST PRODUCTS U67 PAGE POND DIKES U61 AIRPORT AREA U65A W PAGE SWAMP U39 SW HILLSIDE
3	Silver King School	U56A NEAR GOV GULCH U56B NEAR GOV GULCH U31 S HILL/NEAR SMELTER U34 S HILLSIDE U36 S HILLSIDE U61 AIRPORT AREA	U56A NEAR GOV GULCH U56B NEAR GOV GULCH U31 S HILL/NEAR SMELTER U61 AIRPORT AREA U62 FOREST PRODUCTS
4	Mine Timber Company	U59 LINFOR LUMBER U61 AIRPORT AREA U62 FOREST PRODUCTS U64 FAIRGROUNDS U67 PAGE POND DIKES	U59 LINFOR LUMBER U61 AIRPORT AREA U62 FOREST PRODUCTS U64 FAIRGROUNDS U67 PAGE POND DIKES
5	Drive-In Theatre/ Truck Stop	U60 OUTDOOR THEATER U61 AIRPORT AREA U42 I90 R.O.W. U62 FOREST PRODUCTS U59 LINFOR LUMBER	U60 OUTDOOR THEATER U61 AIRPORT AREA U62 FOREST PRODUCTS U59 LINFOR LUMBER U64 FAIRGROUNDS
6	Kellogg Visitor's Center	P01 I90/CDA CORRIDOR U69 CIA U61 AIRPORT AREA U70 GYPSUM POND/DIKES U71 SLAG PILE	U69 CIA P01 I90/CDA CORRIDOR U61 AIRPORT AREA U53 OLD HOMESITES U55 PB SMELT COMPLEX H8 BOULEVARD AREA
7	Kellogg Middle School	U69 CIA U70 GYPSUM POND/DIKES U52 BUNKER CR CORRIDOR U53 OLD HOMESITES U61 AIRPORT AREA U62 FOREST PRODUCTS	U69 CIA U55 PB SMELT COMPLEX U52 BUNKER CR CORRIDOR U53 OLD HOMESITES H8 BOULEVARD AREA U61 AIRPORT AREA U62 FOREST PRODUCTS
8	Mineral Subdivision	U49 NEAR SHOSHONE U53 OLD HOMESITES U69 CIA U50 WTR TRT PLANT U52 BUNKER CR CORRIDOR	U49 NEAR SHOSHONE U51 WAREHOUSE AREA U50 WTR TRT PLANT U53 OLD HOMESITES H8 BOULEVARD AREA U55 PB SMELT COMPLEX
9	Shoshone Apartments	P06 UNDEVELOPED AREA U69 CIA U49 NEAR SHOSHONE U53 OLD HOMESITES P05 VACANT LOT	U49 NEAR SHOSHONE U51 WAREHOUSE AREA H8 BOULEVARD AREA U50 WTR TRT PLANT U53 OLD HOMESITES U55 PB SMELT COMPLEX

Locations and ID numbers can be found in Appendix A4, Figure A4.1.

* See Figure A4-1

Review of Table 4.11 and the results and discussions of the preceding sections can identify those sources most likely to impact the Populated Areas. In Pinehurst the most important wind-blown dust sources are from within the residential/commercial district, the local Pine Creek channel and the SFCDR channel. The high particulate loadings noted in Pinehurst are likely related to local traffic-induced dusts in summer months and wood smoke in winter months. Neither of these sources exhibit metals levels of concern. The highest metals levels observed seemed to be associated with east winds from the remainder of the site.

Significant air pathways in Smelterville are also, likely, related to dusts generated within the area. Several streets and alleys are unpaved and roadside dust and soils had geometric mean concentrations of 4,800 μg/gm Pb, 47 μg/gm Cd, and 111 μg/gm As. The most significant total particulate and lead sources upwind of Smelterville are the Page Pond Dikes (#U67), the Forest Products Area (#U62), Airport Area (#U61), West Page Swamps (#U65a), and the south sloping denuded hillsides west of the Grouse Creek Drainage (#U39). Because of proximity and high concentrations, several sources in the smelter complex, the Fairgrounds (#U64), and Linfor Lumber (#U59) areas could contribute significantly to metals loadings in Smelterville.

Because Kellogg and Wardner span the valley floor from north to south, almost all the sources to the west of town can have substantial impact under particular meteorologic conditions. The most important particulate and lead sources to the Sunnyside Area on the north side of the valley are the CIA (#U69), the Freeway Corridor (#P01), the Gypsum Pond (#U70), Slag Pile Area (#U71), Airport Area (#U61), Lead Smelter (#U55), Old Homesites (#U53) and Boulevard Storage (#H8).

In the Mineral Subdivision, in the center of the valley, the most important sources are the CIA (#U69), Lead Smelter (#U55), Old Homesites (#U53), Boulevard Storage

(#H8), Airport (#U61) and Forest Products (#U62) Areas, and the vacant lot west of the sub-division (#P05, P06). Old Town Kellogg and Wardner are affected by the Smelter Complex (#U55), Old Homesites (#U53), Boulevard Storage (#H8), Mill/ Concentrator Area (#U50, U51, H8), and barren hillsides in the complex area (#U72), and the Bunker Creek Corridor (#U52).

Detailed modeling efforts in the Feasibility Studies (Dames & Moore, 1990d) or to support enforcement orders can, likely, quantify the relative impacts of these sources at particular receptor locations. However, most of these sources, probably have a significant impact at some location within the Populated Areas. It may be sufficient to assess the hazard associated with these sources on the basis of source characteristics detailed in Appendix 4.1.

4.2.4 Summary of Air Migration Routes

The preceding sections have discussed the results of the investigations of the sources, atmospheric transport, loadings, deposition, and fate of airborne contaminants. Concerning migration into or within the Populated Areas, these contaminants present three primary concerns identified as:

- Transport of dusts containing concentrated metals into areas where they can be directly accessed by the resident population, especially children;
- Accumulation of these dusts in reservoirs in the Populated Areas where they represent both a continuing contact source or a recontamination source to remediated soils and surfaces; and
- Transport and deposition of contaminants into areas where they become available to other migration processes that can, in turn, result in human or ecological exposures.

With respect to TSP, levels are generally acceptable throughout the site. Annual average particulate loadings do not vary greatly across the site, ranging from approximately 45-50 $\mu g/m^3$ in Kellogg to 60-70 $\mu g/m^3$ in Pinehurst. However, peak loading concentrations vary considerably, ranging from 500 $\mu g/m^3$ at Pinehurst to 900 $\mu g/m^3$ per 24 hour period at central valley locations. For most of the year, daily TSP levels are below 50 $\mu g/m^3$ with approximately 4 to 18% of daily observations exceeding 100 $\mu g/m^3$ and 2 to 7% exceeding 150 $\mu g/m^3$ depending on monitor location. These days account for a disproportionate share of the annual particulate loading, i.e., the worst 10 to 20 days accounting for 30 to 40% of the total annual loadings.

Most of these extreme loading days are associated with adverse meteorological conditions that combine high wind speeds with dry surface conditions. These events tend to occur in late winter to early spring, late summer, or early fall. The most severe events seem to be associated with frontal conditions exacerbating mountain-valley drainage meteorological phenomena. Some high particulate days at certain monitors seemed unrelated to wind conditions as a suspension mechanism but show high metals concentrations associated with particular sources. This suggests that the responsible emissions might have been mechanically induced at specific sources and locations affecting those monitors. Automobile traffic within the Populated Areas also contributes significantly to particulate and metals suspension.

Notwithstanding anthropogenic source events, the majority of particulate loading at all monitors is explained by particular meteorological conditions including dry surface conditions, wind speeds exceeding 5-8 mph, and directional persistence of two to eight hours. These conditions seem to occur almost exclusively under C and D (neutral) stability conditions with winds originating from the west and west/southwest (approximately 15-20 days per year). On rare occasions, 2-5 days per year, these winds can originate from the east.

These same days also have a marked effect on ambient air metals loadings. With respect to total annual loading, 19% of TSP, 31% of lead and 16% of cadmium occurred at Smelterville during the last two weeks of August and first two weeks of September 1988. It seems that the majority of total metals loadings in the air and total transport occurs in concert with the maximum TSP days. However, with respect to metals concentrations in the dusts, there does not seem to be a one-to-one relationship with TSP. High metals concentrations in the dust can occur under a variety of conditions, and are sensitive to wind direction. Winds blowing from the smelter complex can result in extreme metals levels (i.e., 1 to 4% Pb) at several monitor locations. Geographic variation among monitor locations is also evident. Average seasonal lead concentrations varied from 800 μg/gm at Pinehurst (#1) to 10,000 μg/gm at Shoshone Apartments (#9). Generally, metals concentrations in captured dusts increase from west to east on the site. Monitors near the smelting complex exhibit higher concentrations than those on the north side of the valley.

Particulate deposition was monitored for one year at two monitor locations. One site was downwind from the Smelterville industrial corridor and the other downwind from the CIA. Total deposition and metals content were both higher at the former site. Annual lead deposition rates were 1.0 and 0.3 lbs/acre for lead at the Smelterville and Middle School sites, respectively (#4 and #7). These lead deposition rates could increase soil lead levels by 4 to 12 μg/gm per year, if fully incorporated, in the top inch of mineral soil. Litter layers could be increased by several times this rate.

Measured recontamination rates were not inconsistent with these estimates. Litter and vegetative cover materials seemed to have increased at rates of 10-100's of μg/gm per year at remediated sites. Recontamination was not detectable in surface replacement soils in the three years since remedial action was taken. Based on these data, it seems several years would be required to recontaminate remediated soils and sod to levels of health concern. However, the composition of the recently deposited materials could be of immediate concern. Mean annual concentration of deposited solids ranged from 3,365 to 5,423 $\mu g/gm$ Pb, 68 to 69 $\mu g/gm$ Cd, and 117 to 127 $\mu g/gm$ As at Smelterville Mine Timber and Kellogg Middle School, respectively. Mean weekly concentrations ranged from 527 to 18,868 $\mu g/gm$ Pb, 4 to 358 $\mu g/gm$ Cd, and 13 to 352 $\mu g/gm$ As at the two sites.

Dust metals levels and recontamination rates are estimated to be higher at other locations, particularly those near the smelter or Mill/Concentrator/CIA portions of the complex. In areas near the Shoshone Apartments estimated lead recontamination rates and concentrations in depositing dusts are nearly twice those observed above.

Because the bulk of airborne contaminant transport and deposition seem to be event-related, and the majority occurs under particular meteorologic conditions, those sources most likely responsible for metals transport can be identified. In Smelterville, the largest suspected sources of lead are generally barren areas on the Smelterville Flats and nearby hillsides. The smelter complex and immediate environs have significant impact when east winds occur.

In Kellogg, the Sunnyside area is impacted most by the Smelterville Flats, CIA Beaches and Dikes, and the smelter complex. The Mineral Subdivision is impacted by barren areas east of the CIA, the CIA Beaches and Dikes, the Mill/Concentrator/Boulevard areas, and the Smelter Complex. The Old Town/Wardner areas are impacted by the same sources and the contaminated hillsides in the vicinity of the complex.

In summary, every major lead fugitive dust source in the Study Area likely has an adverse impact. In addition, these dust sources represent both a potential short-term and long-term exposure and recontamination threat to some residential locations. Detailed modeling may be required to quantify the relative effects among sources at different receptor locations. Health risk and remedial needs assessments, however, can likely be based on measured emission estimate characteristics.

4.3 Water Pathways

4.3.1 RI Investigations

Several investigations have been undertaken to assess waterborne contaminant migration pathways identified in Figure 4.2. The bulk of the efforts have been accomplished in the Non-populated Areas RI and include elements of several major tasks performed by the PRP. Table 4.12 shows the major elements of the Non-populated RI (GRC, 1987).

Table 4.12

ORGANIZATION OF THE NON-POPULATED AREAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY (RI/FS)

Remedial Investigation	Completion Date
Task 0 - Determination of Contaminants of Concern	1988
Task 1 - Soils and Surficial Materials Investigation	1989
Task 2 - Surface Water Investigation	1990
Task 3 - Groundwater Investigation	1991
Task 4 - Air Investigation	1991
Task 5 - Vegetation and Terrestrial Biology Investigation	1990
Task 6 - Central Impoundment Area (CIA) Investigation	1991
Task 7 - Page Pond Investigation	1990
Task 8 - Bunker Ltd. Smelter Complex Investigation	1990
Task 9 - Remedial Investigation Report	1991
Task 10 - Public Health Evaluation	1991
Task 11 - Supporting Investigations	1991
Feasibility Study	
Task 12 - Screening of Remedial Technologies	1992
Task 13 - Focused Feasibility Study	1992
Task 14 - Development and Evaluation of Alternative Remedial Actions	1993
Task 15 - Feasibility Study Report	1994

The **Surface Water and Aquatic Biology Investigation** emphasizes sampling and analysis of surface water bodies. Information has been collected on contaminant mass loadings, ambient water quality conditions, sediment characteristics, runoff, stream and tributary flows, benthos and fish composition, abundance, and bio-assays of specific aquatic organisms. In the **Groundwater Investigation** existing wells have been inventoried. Surveys have been performed to evaluate valley fill materials, underlying geology, and aquifer characteristics. Monitoring wells have been established and numerous geohydrologic and chemical data have been collected. Contaminant sources have been identified and comprehensive flow and contaminant transport modeling efforts are anticipated. Under the **Vegetation and Terrestrial Biology Investigation**, extensive erosion assessments and modeling have been undertaken. Both sheet and gully erosion have been evaluated in relation to soil type, topography and vegetative cover on the hillsides portion of the site.

The **CIA Investigation** and the **Page Pond Investigation** concern large confined tailings piles serving as waste water impoundments with associated discharges to both surface and groundwaters. Extensive studies have been undertaken to monitor flows and contaminant loadings at both of these facilities. Two special efforts are being undertaken in the **Smelter Complex Investigation** to address both surface and groundwater components of contaminants migration at the industrial facility. For surface waters this includes delineating drainage basins, identifying waste sources within sub-basins, evaluating the status of existing drainage systems, and collecting and analyzing runoff and sediments. A separate effort will characterize groundwater beneath the smelter complex with respect to water quality, flow, and aquifer parameters, and to identify contaminant sources.

The results of these combined investigations will provide the data necessary to develop a comprehensive assessment of waterborne contaminant migration on a sitewide basis. That evaluation will be accomplished as part of the Feasibility Study and Risk Assessment efforts envisioned for the Non-populated Areas.

In contrast, only limited studies have addressed the water pathways in the Populated Areas. This is because surface and groundwater investigations have been a major area of emphasis in the Non-populated Areas and because fewer waterborne contaminant issues directly affect the Populated Areas, especially as human exposures are concerned. The major concerns related to waterborne transport of contaminants within, or into, the

Populated Areas can be summarized in three areas. Those are:

- Use of or the development of local water sources for potable water, irrigation, or industrial supplies;
- Movement of contaminants into, or within, the Populated Areas by runoff and storm events; and
- Leaching of contaminants from soils and subsoils in the area.

Because of the availability of ARARs for potable water supplies, that issue is addressed in Section 3 of this document. The mass transport of solids into the Populated Areas is discussed below in Section 4.3.2 as it relates to waterborne erosion on a sitewide basis. The issue of leaching has four components, relevant to the Population Areas, including:

- In-situ leaching as a source of groundwater contamination,
- Disposal characteristics of contaminated soils,
- Sub-soils as a source of recontamination to remediated areas (upward migration or biological translocation), and
- The mineral soil's role as an ultimate sink of deposited metals.

All of these components are discussed as they relate to environmental persistence and mobilization or immobilization issues in Section 4.3.3.

4.3.2 Water Erosion/Mass Loading Studies

Results of erosion modeling studies conducted in the Non-populated Areas were reported in May of 1990 (Dames & Moore, 1990b). The site was divided into 80 areas similar to those described in the fugitive dust assessment effort discussed in Section 4.2. Both sheet wash and rill erosion were evaluated using the Universal Soil Loss Equation (USLE). (Dames & Moore, 1990b).

Figure A4.6 and Table A4.2 in Appendix A4.2 show the surface erosion study units and annual soil loss computation estimates, respectively. Although these results project maximum rates and have not been calibrated to observed runoff or mass loadings, the results provide a relative ranking of those units where greatest waterborne erosion rates are expected. Figure 4.7 shows the locations of ten units with the highest annual total erosion in tons/year. These ten units encompass 1,937 acres and account for 379,570 tons/year in total, or approximately 46% of the site hillside mass loading total. Several large units are included in this list. Figure 4.8 shows those units with the highest sheet and rill erosion rates in tons/acre/year. This list largely includes the same hillsides in the immediate vicinity of the smelter complex on the south side of the valley.

Gully erosion was also evaluated for the site (Dames & Moore, 1990b). Sixteen areas of active gully erosion were identified. Ten of these gullies were studied in detail to qualitatively evaluate erosion potential under current conditions. Those gullies are identified in Figure A4.7 and Table A4.3 in Appendix A4.2. Estimated age and present and projected gully dimensions are shown. Table A4.4 in Appendix A4.2 summarizes anticipated erosion volume over the next fifty years under current conditions. All of the major gullies are located in the barren drainages identified as major sheet and rill erosion sources.

Vegetative cover was identified as a key variable in projecting future gully erosion rates. A weighted cover variable for the various units was calculated and is presented in Figure 4.9. This weighted value shows that the least cover and greatest erosion rates are nearest the smelter complex. The same drainages flow to and through the Populated Areas near Smelterville to either the South Fork of the Coeur d'Alene River or the Page Swamps.

Areas near the smelter complex also demonstrate the highest contaminant concentrations. This combination could result in significant waterborne contaminant migration to the Populated Areas, either in the form of sediments collecting in the

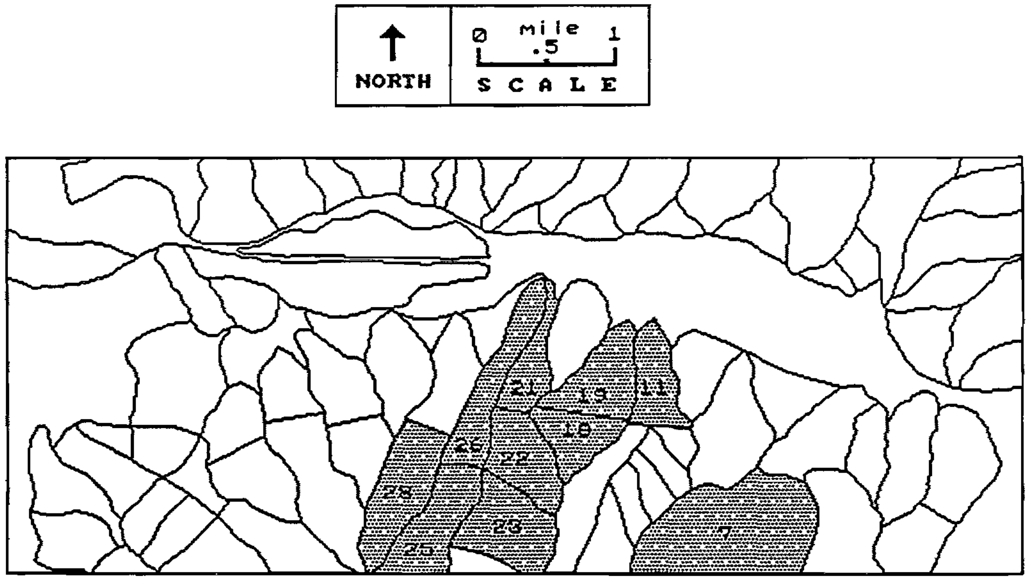


Figure 4.7 - Hillside Erosion Areas Ranked by Total Soil Loss (tons/year)

Area No.	Drainage Area (acres)	Soil Loss (tons/acre/yr)	Total Loss (tons/year)
23	206.0	359	73857
25	185.0	347	64156
28	217.0	192	41633
22	163.8	228	37342
7	473.6	63	30030
18	121.6	240	29184
11	124.2	226	28067
21	103.0	254	26197
19	164.5	152	24954
26	177.9	136	241251
TOTAL	1936.6	2196	379570

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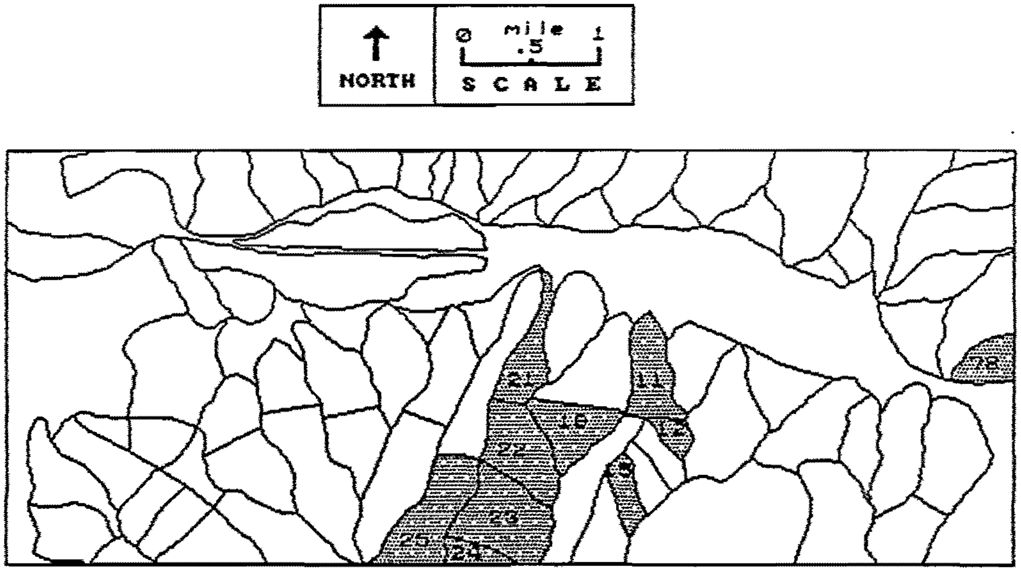

Figure 4.8 - Hillside Erosion Areas Ranked by Soil Loss Rate (tons/acre/year)

Area No.	Drainage Area (acres)	Soil Loss (tons/acre/yr)	Total Loss (tons/year)
23	206.0	359	73857
25	185.0	347	64156
24	42.9	329	14133
21	103.0	254	26197
18	121.6	240	29184
22	163.8	228	37342
11	124.2	226	28067
12	36.5	213	7791
78	49.3	213	10480
15	59.5	210	12513
TOTAL	1091.8	2619	303719

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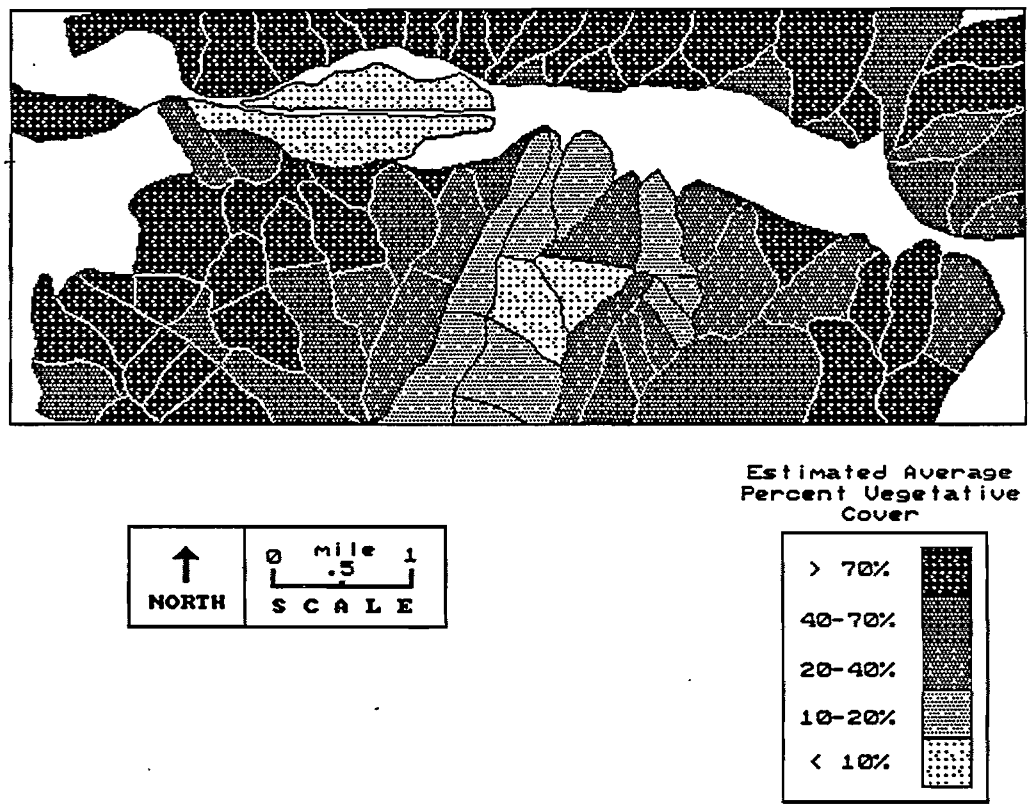

Figure 4.9
Estimated Average Vegetative Cover by Area (percent)

drainage ways, or flooding if the drainway capacities are exceeded. Table 4.13 summarizes sediment metals contents measured in these drainages and the South Fork of the Coeur d'Alene River. Metals contents in sediments from hillside drainage range from 650 to 13,100 μg/gm Pb, 6 to 16 μg/gm Cd, 10 to 158 μg/gm As, and 760 to 4,600 μg/gm Zn are noted.

Table 4.13

METALS LEVELS FOR SEDIMENT SAMPLES COLLECTED FROM HILLSIDE DRAINAGE AND SMELTERVILLE FLATS LOCATIONS
(all units in μg/gm in <200 mesh sample)

	Sb	As	Cd	Cu	Fe	Pb	Mn	Hg	Zn
Hillside Sediment									
Maximum Value	15.6	158.0	16.30	191.0	62100	13100	22300	1.92	4640
Minimum Value	12.0	10.0	6.10	26.8	17000	652	1000	0.98	768
Arith. Mean	12.7	55.2	10.24	75.8	33800	5077	5047	1.41	1958
Geom. Mean	12.6	36.3	9.53	32.9	29781	2511	2535	1.39	1520
Count	7	7	7	7	7	7	7	7	7
Smelterville Flats Sediment - (Flood Plains North of I-90)									
Maximum Value	64.4	449.0	133.00	572.0	164000	21100	14200	9.13	10200
Minimum Value	14.8	132.0	67.60	259.0	43700	4220	2930	4.70	5700
Arith. Mean	43.2	331.3	91.20	383.3	108200	13545	9510	7.21	7735
Geom. Mean	37.7	300.8	86.80	366.4	96127	11436	8077	6.93	7551
Count	4	4	4	4	4	4	4	4	4
Smelterville Flats Sediment - (Commercial Zone Northeast Residential)									
Maximum Value	48.2	305.0	111.00	403.0	71600	9180	25500	5.80	11700
Minimum Value	12.2	93.3	75.20	215.0	30200	2410	5160	5.30	7020
Arith. Mean	30.2	199.2	93.10	309.0	50900	5795	15330	5.55	9360
Geom. Mean	24.2	168.7	91.40	294.0	46501	4704	11471	5.54	9063
Count	2	2	2	2	2	2	2	2	2

4.3.3 Environmental Persistence/Dissolved Metals Migration

The mobility of metals in solution in the soil profile, contaminant migration in groundwater, and the fate and sinks for various metals are all related to their respective capacity to leach. Mobilization of metals between the solid and liquid phases of soil and subsequent migration in the groundwater and soil solution are complex processes, often best described empirically. This section briefly describes the persistence of metals in the soil as it relates to mobilization or immobilization for several metals. The results of leachate tests are then reported and discussed.

The mobility of contaminants in environmental media is dependent on a number of factors. Among the most important concerns are the physical and chemical characteristics of the contaminant and the media. Several project documents have discussed environmental mobility, usually as it pertains to a specific metal's characteristics and its propensity to partition various environmental compartments. Relative to the contaminants of concern in the Populated Areas and waterborne migration, solubility and sorption are likely the most important considerations. With regard to soils, trace metals are normally distributed between the liquid and solid phase of the soil column. The liquid phase of the soil column can be either free liquid in the pore spaces at or below the water table, or exist as a thin film of moisture in intimate contact with the solid phase in the vadose zone. In the liquid phase, metals exist as free ions or as soluble complexes with organic or inorganic ligands. Organic ligands are typically fulvic and humic acids and inorganic ligands may be iron or manganese oxides.

In the solid phase, metals may be incorporated into the crystalline minerals of the parent rock or secondary clays, or precipitated as insoluble organic or inorganic complexes. Metals may also adsorb onto the surface of any of these solid forms. The availability of these metals to leach to the groundwater, for uptake by flora and fauna, or to translocate in solution is determined by the equilibrium distribution between liquid and solid phase.

The most mobile form of the metal is in the moisture film surrounding soil particles. From there, metals can move to the free water for transport or into plant roots or microfauna for translocation. The least mobile forms are in the parent rock derivatives where the metals may be bound in crystalline structures. The mobility for complexes and precipitates is intermediate to these extremes and is generally sensitive to chemical environment of the soil. Important factors influencing solubility are the availability of organic matter, pH, and presence of specific inorganic ions. The reverse of mobility, immobilization, is dependent on the solid phase form, the tendency toward transformation to less soluble forms by precipitation, ion exchange with hydrous oxides or clays, or by chelation with humic or fulvic acids.

As a result, the availability of the metals to migrate in solution within or from contaminated soils in the Populated Areas can be expected to depend on the metal forms, moisture content, and the specific soil-chemical environment. Lead, the predominant contaminant of concern for the site, tends toward immobilization. The parent compounds of galena and lead carbonates from mine and mill discharges, and lead oxides from pyrometallurgical operations are relatively insoluble in water at normal pH. Sorption seems to be the dominant process affecting the distribution of lead in the soil with both inorganic and organic adsorption favoring insoluble compounds. As a result, the accumulation of lead in soils is primarily a function of the rate of deposition. Most lead is retained in the upper soil layers and relatively little passes to surface or groundwaters as leachate. However, at this site where contamination is widespread, sufficient amounts of lead do leach to the groundwater to exceed the MCL.

In surface waters, lead dissolved from local sulfide ores tends to combine with carbonate or sulfate ions to form insoluble compounds. Lead is noted for its tendency to form low solubility compounds with the major anions of natural waters. As a result, lead is generally not expected to migrate significantly in solution. Again, however, dissolved lead concentrations in the upper aquifer routinely exceed the MCL. The major sinks of lead expected for the Populated Areas are the surface layers of the mineral soil and sediments.

As opposed to lead, some of the other notable contaminants of concern are expected to be mobile in solution along water pathways. Zinc and cadmium are among the more significant and show similar chemistry in natural waters and soil solutions. Both exhibit a valence of +2 in aqueous environments and are readily transported in surface and groundwaters. Sorption processes are dominant determinants in both metals' fate in natural waters. In aerobic environments, zinc will precipitate and partition into sediments by sorption onto hydrous ion and manganese oxides, clays and organic material. In a reducing environment, zinc can be released and readily pass into solution. Zinc is not likely immobilized in soils to the extent of lead, and may be continually available to waterborne pathways with an ultimate sink in the sediments.

A significant factor in cadmium fate and transport is its ready ability to complex with organic matter in solution. Cadmium is strongly bioavailable and bioaccumulates at all trophic levels. Cadmium can leach to the groundwater and is readily taken up by plants, where it is available to the food chain, and could tend to bioaccumulate in the organic soil horizon.

Arsenic exhibits the most complex soil chemistry of the site contaminants. In soils, arsenic can exist in a variety of forms and two valence states, +3 and +5, with markedly different chemistries. Many arsenic compounds are easily to moderately soluble in water, while others are largely insoluble. Soluble forms may be mobilized into groundwater, but sorption can restrict migration. Interconversions between insoluble and soluble forms can occur and microorganisms can convert insoluble or adsorbed arsenicals to soluble organic derivatives. In most soils, especially those with high clay content, arsenic is usually well-retained and leaching is not extensive. Arsenic chemistry in the aquatic environment is even more complex, exhibiting stability in four valence states. Arsenic is extremely mobile in natural waters and can cycle between the water column, sediments and biota. Soils and sediments seem to be the primary, but not an ultimate environmental sink for arsenic.

The other metals of concern are difficult to assess. Copper, manganese, antimony and mercury tend either to occur in low concentrations relative to the metals discussed above, or have poorly understood soil chemistry in this type of environment. Additional analyses of contaminant migration in surface and groundwater will be conducted in the Non-populated Areas RI/FS.

Most of the concern regarding contaminant migration in solution in the Populated Areas is related to the leachability of area soils. Several soil samples were subjected to leach tests for disposal considerations. These same results can provide some insight to metals migration potential in Populated Areas soils. Table 4.14 shows summary results for soils for the USEPA Extraction Procedure Toxicity (EPTox) test.

Table 4.14

EPTOX ANALYTICAL RESULTS FOR THE 23 SOIL CORES TAKEN FROM KELLOGG, SMELTERVILLE, PINEHURST, WARDNER, AND PAGE

Metal Concentration (µg/L)

Sample	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
1	ND	340	15	ND	179	ND	ND	ND
2	ND	276	4	ND	250	ND	ND	ND
3	ND	232	27	ND	4040	ND	ND	ND
4	ND	505	303	ND	4140	ND	ND	ND
5	ND	472	230	ND	4660	ND	ND	ND
6	ND	322	81	ND	3280	ND	ND	ND
7	ND	517	75	ND	1620	ND	ND	ND
8	ND	414	19	ND	566	ND	ND	ND
9	ND	790	192	ND	4040	ND	ND	ND
10	ND	670	163	ND	4600	ND	ND	ND
11	ND	416	28	ND	457	ND	ND	ND
12	ND	626	6	ND	244	ND	ND	ND
13	ND	1310	152	ND	4280	ND	ND	ND
14	ND	962	34	ND	313	ND	ND	ND
15	ND	473	158	ND	3690	ND	ND	ND
16	ND	856	25	ND	161	ND	ND	ND
17	ND	865	72	ND	3830	ND	ND	ND
18	ND	759	138	ND	8560	ND	ND	ND
19	ND	484	125	ND	3820	ND	ND	ND
20	ND	915	31	ND	156	ND	ND	ND
21	ND	213	12	ND	82	ND	ND	ND
22	ND	579	85	ND	5720	ND	ND	ND
23	ND	160	234	ND	49800	ND	ND	ND

ND = Concentration below the instrument detection limit.

EPTox Critical Levels (µg/L)

As, Cr, Pb, Ag	5000
Ba	100000
Cd, Se	1000
Hg	200

The sample set shown in Table 4.14 was selected to ensure that EPTox results would represent a conservatively high estimate of any hazardous characteristic of the residential soil. (See Appendix B). The top 6-inches of 23 of 40 soil cores collected during the 1987 soil core sampling program were used for this analysis. The cores selected were those reporting the highest total lead (Pb) levels (based on portable X-ray fluorescence analyses) from Kellogg, Smelterville, Pinehurst, Wardner, and Page. Eight cores were selected from Kellogg, six from Smelterville, and three from each of the other three communities.

The arithmetic mean EPTox Pb value for the 23 samples was 4,600 µg/L in the extracted leachate. Three of 20 samples exceeded the 5,000 µg/L standard for lead. The concentrations for these samples were 8,560, 5,720, 49,800 µg/L (Table 4.14). All other metal analytes (arsenic, barium, cadmium, chromium, mercury, and selenium) concentrations were also below the EPTox critical levels, with many reporting below instrument detection limits. Further information on soil core analytical results are reported in Appendix B.

These data indicate that migration of contaminants in solution from soil is not likely a major problem for residential soils in the Populated Areas either in-situ or as a consideration in disposal requirements. However, recent analyses regarding the possibility of upward flow of metals from shallow groundwater table fluctuations indicate that significant amounts of lead may be mobilized at isolated locations in the Populated Areas. Locations at greatest risk are those where high water tables coexist with severe contamination at depth. Some of these areas might be subject to recontamination of clean soils through solution migration of contaminants from below (CH2M HILL, 1990f).

4.3.4 Summary of Water Migration Routes

Several investigations are underway to assess the significance of contaminant migration by water pathways on the site. Most efforts are focused in the Non-populated Areas RI.

Those efforts of significance to the Populated Areas can be considered in three categories. Those are potable water sources, mass movement in storm and runoff events, and leaching of contaminants from residential soils.

Health officials are aware of no public water supplies exceeding Maximum Contaminant Levels (MCL) in the area. However, most potential sources in the area exceed MCL's and virtually all potable water is imported from outside the site boundaries. Future population growth and demands within the site and remedial needs may require the development of additional potable water sources.

Water erosion of hillsides near the smelter complex is a potential concern. Mass loading rates are high from these steep barren locations. Both sheet and rill erosion are significant, with several large gullies developing in the same general area. Sediment loading and metals contents are high throughout the site, averaging 5,000 μg/gm lead on the hillsides, 5,800 μg/gm lead in the commercial areas north of Smelterville, and 13,500 μg/gm lead in the Smelterville Flats.

These gullies and drainages exit to the SFCDR through the Populated Areas. Smelterville is especially prone to flooding during peak rainfall and snowmelt events. Significant sediment loads have entered Smelterville through floods twice in the last ten years. Erosion control efforts will be necessary to minimize exposure to contaminated solids and to prevent recontamination of remediated sites.

Contaminant migration in solution does not seem to be a widespread problem with regard to residential area soils. EPTox tests show dissolved metals levels far below standards for all metals excepting lead. Some samples show EPTox concentrations exceeding the 5,000 μg/L standard, but it is doubtful that composited soils would yield results approaching this level. Lead is, likely, largely immobilized in this environment. However, zinc, cadmium and arsenic migration could be a significant concern in the Non-populated Areas.

4.4 Solids Movement Pathways

4.4.1 RI Efforts

In addition to contaminant transport on site due to air and water pathways, migration can also occur as a result of mechanical movement of solids. Translocation of solids by mechanical means is an important migration mechanism on this site. Mineral industry activities routinely transport large amounts of product, wastes and by-product materials through and within the site boundaries. Massive removal, relocation and stabilization efforts are anticipated for solids stored within the smelter complex. Those activities are being addressed as part of the Non-populated Areas RI and are considered in this document only to the extent of potential impacts in the Populated Areas.

Mechanical transport of materials into, and within, the Populated Areas has been addressed in three portions of the RI/FS efforts. Samples from particular fugitive dust sources (i.e., parking lots), roadsides, and railroad right-of-ways demonstrate high metals levels indicative of ore spillage and tracking, as well as these areas' potential as continuing contaminant migration sources. Solids contaminant levels for these areas were presented in Section 2.2.

Solids movements in the soil column, (i.e., translocation of contaminants vertically in the soils) is being investigated as part of the Feasibility Study effort. Also being addressed in feasibility efforts are Institutional Controls (rules and regulations, landuse restrictions, etc.) that might be used to regulate, among other concerns, solids movement activities within the site. These controls are being evaluated both as a tool to limit human exposure and contaminant migration and preserve the integrity of applied remedies through ensured maintenance and oversight.

4.4.2 Mechanical Transport of Solids Into and Within the Populated Areas

Examples of mechanical movement of wastes on site include:

- Spillage of minerals processing materials in transit along roads and right-of-ways;
- Tracking of these materials out of the industrial areas onto streets and into the community;
- The use of mine and smelter wastes for fill, cover, or construction amendments in the community
- The movement and placement of contaminated soils during routine construction and excavation activities; and
- The tracking of contaminated soils into homes and buildings by human activities and pets.

These types of activities certainly contribute to the ubiquitous nature of surface soil and dust contamination in the Populated Areas nearest the smelter and mine/mill complex. Conversely, the high contamination levels observed on roadsides, right-of-ways and most surface soils throughout the area serve as a continuing source of material for solids migration. Table 4.15 summarizes the solids materials that could be potentially translocated by vehicular, human, or pet activities throughout the site.

Several concerns evolve from these potential migration processes. Many of the materials exhibit extreme concentrations, as evidenced in the fugitive dust source inventories presented in Table 2.12. Lead concentrations ranged to 20-40% in parking lots at the complex with more than 30% of the sample passing 200 mesh sieve. These soils could easily be picked up on vehicles in wet weather and tracked into adjacent commercial and residential areas. The high levels of contamination along roadsides in these areas, 249 μg/gm to 60,100 μg/gm Pb, 3 μg/gm to 487 μg/gm Cd, and 19 μg/gm to 810 μg/gm As, anecdotally support that this process is ongoing.

Once tracked into residential and commercial areas, these materials are available to be carried into yards and homes through air and water transport, or as solids adhered to shoes, objects, and pets. In the residential environment these contaminants are then available for human contact and intake.

The use of mineral industry by-products; or the excavation, exposure, and redistribution of contaminated soils and tailings through routine construction, underground utility, or site development work has additional concerns. Not only are these potential sources of human contact and further migration, but such activities could easily damage remedial techniques being employed in the area. Many homes and public access areas have been remediated through removals and establishment of clean soil and sod barriers. Construction activities exposing sub-surface contaminants or employing mineral industry by-products in placement actions could endanger the effectiveness of the remedies.

Table 4.15
POTENTIAL SOLID-MATRIX MASS MIGRATION ACTIVITIES, SOURCES, CONCENTRATIONS, IMPACTS

Type of Activity	Source Material	Concentrations Observed (μg/gm)	Potential Concerns
Spillage in Transit	Ores, Wastes, Industrial By-Products	10000-500000 Pb, Zn 5000-50000 Cd, As, Sb, Cu 100-5000 Hg	Contamination of Roadsides, Right-of-ways, adjacent properties, surface water; human contact; recontamination of remedies.
Tracking of Spillage	Transit Spills, Parking Lots, Storage Areas, Flood Deposits/ Sediments	10000-300000 Pb, Zn 5000-50000 Cd, As, Sb, Cu 100-5000 Hg	Contamination of Roadsides, Right-of-ways, adjacent properties, human contact; surface water; recontamination of remedies.
Use of Mineral Industry By-Products	Mine Waste Rock, Tailings Sand, Slag	500-40000 Pb, Zn 100-10000 Cd, As, Sb, Cu 100-10000 Hg	Source of recontamination, and human contact, potential groundwater, and surface water contamination
Construction Activities	Contaminated Soils, Tailings	100-40000 Pb, Zn 100-10000 Cd, As, Sb, Cu	Source of recontamination and human contact; potential groundwater, and surface water contamination; recontamination of remedies
Tracking by Human and Pet Activities	Contaminated Soils, Tailings	100-40000 Pb, Zn 100-10000 Cd, As, Sb, Cu	Source of recontamination, and human contact; potential groundwater, and surface water contamination; recontamination of remedies

Once these contaminants are exposed in the residential environment they are available to the human population and to additional migration mechanisms that can move the material into homes and yards.

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5.0 EXPOSURE ASSESSMENT

An exposure assessment for the residential population evaluates potentially critical exposures to site chemicals of concern. This is achieved by:

- Identification of environmental media that are or may be contaminated by chemicals of concern.
- Identification of populations that may come in contact with these media.
- Identification of specific locations (exposure points) and pathways where contact is likely or plausible.
- Determination of representative and extreme concentrations of contaminants at these exposure points.
- Characterization of the routes by which populations may be exposed, and estimation of potential exposure for each route.
- Estimation of consequent contaminant intakes associated with each of the critical exposure pathways.

An assessment of potential and real human exposures and consequent contaminant intakes by residents in the Populated Areas of the Bunker Hill site are presented here and in Sections 4 and 7 of the PD (JEG et al., 1989).

Receptor populations at risk are identified as the current and past residents of the Populated Areas of the site. Residents of three local community groups will be evaluated for determination of risk due to chronic exposures to carcinogens and noncarcinogens; these groups are: 1) Smelterville; 2) Kellogg/Wardner/Page; and 3) Pinehurst. Section 5 of the PD identifies the populations and sensitive sub-populations at risk. Sensitive populations are at greatest risk due to either: 1) greater inherent susceptibility; or 2) exposure situations peculiar to that group. The PD identifies two critically sensitive sub-populations with regards to lead exposure near the site which may also be applicable to other site chemicals of concern. These are: 1) **preschool-age children**; and 2) **pregnant**

women due to the risk experienced by the conceptus. For the Populated Areas risk assessment, three basic groups will be evaluated in terms of contaminant exposures and consequent risks. These are:

1. A general population of residents that are assumed to live, since birth, under the conditions represented by the contamination levels found since 1983 (referred to as the current scenario);

2. A general population of residents who were born in 1971 and were 2 years old during the period of maximum exposure on-site and who remain on-site for a 70-year lifetime (referred to as the historical scenario); and

3. A sensitive sub-population of children exposed to lead.

Historical exposures, since 1971, are evaluated due to documented high contaminant concentrations during 1973-1975 which affect average chronic risk for a large portion of the current residents. Airborne lead concentrations were approximately 100 times greater during this period than current levels. Consideration of these exposures is especially critical for evaluating the potential chronic risks of metal contaminants on sensitive subpopulations. Residual and latent effects of past metal exposures result in body burden accumulation, chronic disease and/or carcinogenesis. Approximately 95% of the total body burden of lead is found in bone and serves as a significant reservoir that is released especially during pregnancy, lactation, osteoporosis, and various disease states in adults, resulting in maintenance of blood and soft tissue lead levels long after periods of exposure have ended (lead half-life in bone is typically 10-27 years). Extreme historical exposures and consequent accumulations of lead are considered in the evaluations of chronic (lifetime) exposures. Historical exposures to contaminants other than lead are evaluated in terms of potential chronic health risks.

The current baseline (assuming no-action as a remedial alternative) assessment is represented by 1983, 1986, 1988, and 1989 conditions and environmental media concentrations. This period follows closure of the smelter (in 1981) and is reflected in a significant reduction in population exposures, especially via the air route. The year 1983 is selected to represent the beginning of the current scenario for baseline exposures due to the availability of environmental media and blood lead data for this site, only one year prior to the implementation of a comprehensive Community Health Intervention Program and the beginning of Superfund activities. This represents a time following smelter closure when the site and its attendant population are expected to be least affected by remedial intervention. Also, a 1983 Lead Health Study data base and results were significant factors in the site's ranking on the USEPA National Priorities List (NPL). The 1983 conditions are expected to be representative of an "unaffected" lead dose-response relationship experienced by the community during the 1980s environmental conditions.

Exposure evaluation and risk assessment are accomplished with seven site contaminants of concern. These contaminants are all metals that exhibit enrichments in soils and dusts relative to background levels, show decreasing concentrations as a function of distance from the site, and exhibit varying degrees and mechanisms of toxicity with corresponding toxicological profiles (see Section 3 of the PD). The chemicals of concern are **antimony, arsenic, cadmium, copper, lead, mercury**, and **zinc**.

The principal exposure media and associated receptor pathways characterized for the evaluation of **baseline** human health **risk** for the typical resident in the Populated Areas of the Bunker Hill site are:

- Ingestion of residential surficial yard soils,
- Ingestion of house dusts,
- Inhalation of air particulate matter, and
- Consumption of national market basket variety produce and water ingestion from public water supplies.

National market basket variety produce and associated contaminant intakes represent exposures that all typical residential members of the site and off-site population experience due to consumption of average national market basket variety produce. Contaminant content and associated metal intakes of market basket produce are provided by the U.S. Food and Drug Administration (USFDA) and summarized in Tables A5.1, A5.2 and A5.3 of Appendix A. Significant reductions in national market basket food content over time are noted for arsenic, cadmium and lead. These reductions are attributed to USFDA and other governmental efforts for lowering potentially toxic metal content in food introduced during food processing, handling and production.

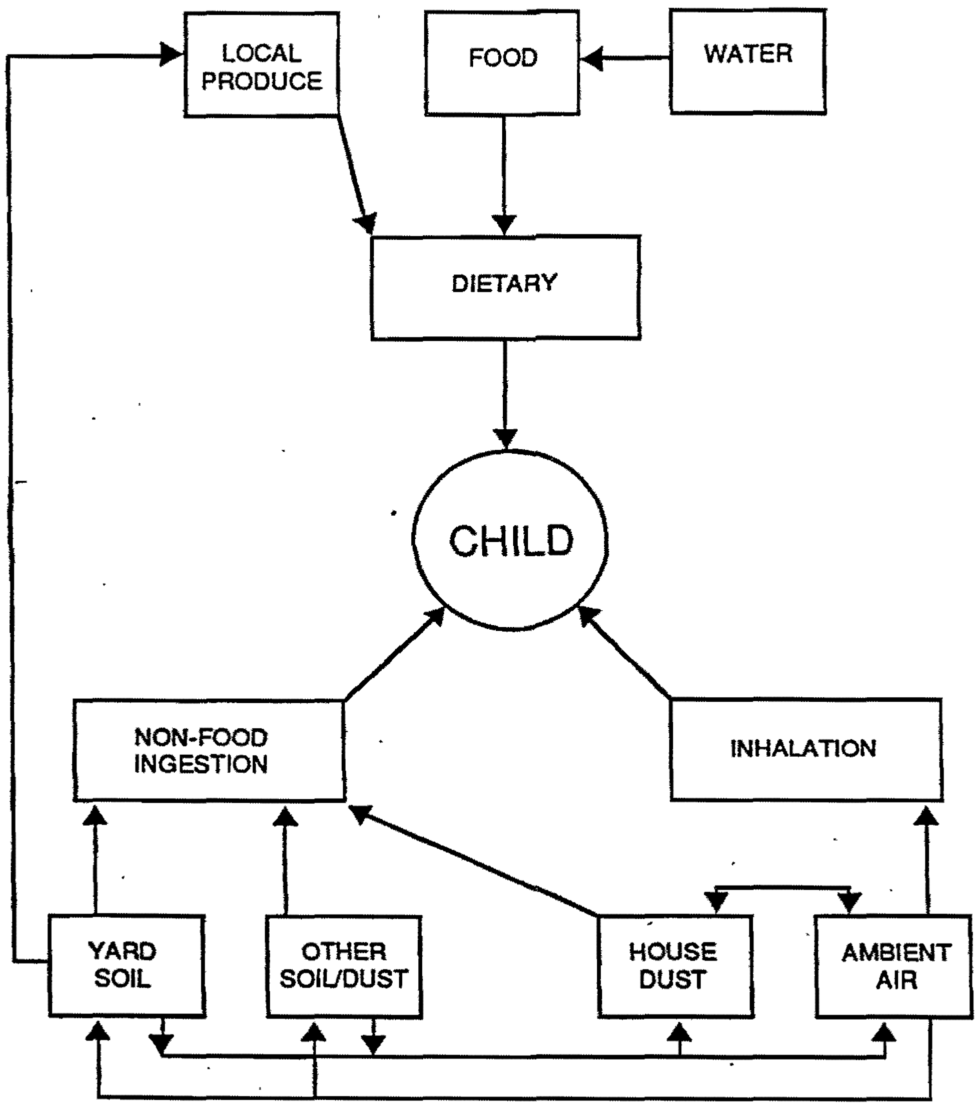
Figure 5.1 presents an abbreviated pathway model showing principal exposure routes and media for the typical child. This model is also appropriate for nonoccupational or adult residential exposures.

Additional exposures that could be experienced by members of the population who engage in potentially high risk activities are evaluated as **incremental** exposures. Incremental exposures are associated with:

- Consumption of contaminated local groundwater,
- Ingestion of other soil/dust at extreme residential soil and house dust concentrations (at the 95 percentile residential yard soil and house dust concentrations),
- Ingestion of extreme amounts of soil and dust during childhood, typical of "pica-type" behavior (ingestion rate of 1 gm/day of soil/dust for ages 2 through 6),
- Consumption of local fish from the Coeur d'Alene area,
- Consumption of local vegetable garden produce, and
- Inhalation of outdoor air particulate matter during episodic, high wind events.

Figure 5.1

Abbreviated Pathways Model Showing Primary Exposure Routes for Children



Lifetime or **chronic** exposures are evaluated for the typical resident using average media concentrations. Chronic exposures at extreme levels are not expected for the typical resident; exposures to environmental media at extreme concentrations may be significant for either short-term periods or for only a few members of the population. Arithmetic mean concentrations are typically used to represent environmental media concentrations for the evaluation of average or typical exposures and consequent contaminant intakes. Other statistically representative values may be employed for the evaluation of population exposures; these may include the use of medians, percentile distribution thresholds, geometric means, or extreme values. Any of these values may be used to evaluate specific activities or segments of receptor groups. For this evaluation, arithmetic mean concentrations for exposure media are used to represent average or typical long-term exposure levels. For residential soil and house dust exposures, geometric mean concentrations are calculated and used for evaluating typical long-term exposures for this population group. Geometric mean values for these media are expected to be more representative of average exposures due to the statistical distributions exhibited by soil and house dust metal concentrations. The metal concentrations distribution profiles for these media are skewed at high concentrations due to a small number of samples in the extreme concentrations range. The central tendency, or average concentrations, for these types of distributions are better estimated by geometric means rather than arithmetic means, which may result in high average estimates due to a few high concentration values. Arithmetic mean values are determined as:

$$AMean = \frac{1}{n}\sum_{i}^{n} X_i$$

and geometric means are determined as:

$$\text{GMean} = \sqrt[n]{X_1 \cdot X_2 \cdots X_n} = e^{(\sum_i^n (\ln X_i)/n)}$$

where: X_i = i^{th} value of data set

n = total number of values

For any given set, GMean ≤ AMean.

Chronic (long-term) exposures to extreme concentrations of site contaminants are not evaluated in the baseline chronic assessment. Extreme media concentrations represented as 95th percentile levels are evaluated as **incremental** and **sub-chronic** (short-term) exposures. Total intakes associated with various potentially high risk activities in an incremental analysis are determined by adding any combination of the incremental intake estimates for each scenario to the respective chronic (long-term) estimate, yielding a total combined intake. Table 5.1 presents a summary of contaminants of concern, exposure routes and sources, and scenarios addressed in the exposure evaluation and risk assessment.

5.1 Exposure Point Concentrations

Representative concentrations for contaminants in environmental media and at population exposure points are derived from data and sources described in Section 2 of this report and Section 4.3 of the PD.

5.1.1 Soil Concentrations

Contaminant levels in residential surficial yard soils are available from the 1974, 1975 and 1983 IDHW Health Surveys and the 1986/87 soils data base from the Bunker Hill

Table 5.1
Contaminants Evaluated, Exposure Routes and Sources, and Exposure Scenarios Addressed in the Risk Assessment

CONTAMINANTS EVALUATED

Antimony
Arsenic
Cadmium
Copper
Lead
Mercury
Zinc

EXPOSURE ROUTES AND SOURCES

Chronic -
Baseline:

Inhalation - Air/particulates
Ingestion - Soil
Ingestion - House dust
Ingestion - Other soils and dusts
Ingestion - Drinking Water (Municipal Water System)
Ingestion - Market basket produce

Incremental:

Ingestion - Local fish (Lake Coeur d'Alene)
Ingestion - Locally grown garden produce
Ingestion - Drinking Water (on-site groundwater)
Ingestion - Extreme soil/dust consumption rate, "Pica Behavior" (as a child)
Ingestion - Other soils and dusts (maximum estimated exposure)

Subchronic -
Dose-Response Modeling for Lead

EXPOSURE SCENARIOS

Historical - Smelterville
Current - Smelterville
Historical - Kellogg/Page/Wardner
Current - Kellogg/Page/Wardner
Historical - Pinehurst
Current - Pinehurst
Background

Populated Areas RI/FS (IDHW, 1974; IDHW, 1975; IDHW, 1983; CH2M HILL, 1990a). Concentrations for periods in which data are not available are estimated by utilizing the most recent monitoring results. The baseline exposure evaluation assumes that environmental media concentrations will remain constant from the most recent analyses. Geometric mean concentrations in surficial mineral soils for each of the Populated Areas (Smelterville, Kellogg/Wardner/Page and Pinehurst) are used for evaluating chronic exposures for typical members of the population. Extreme concentrations represented in the upper 95th percentile level will be evaluated as incremental exposures to "other soils and dusts." Table 5.2 summarizes the mean and extreme metals concentrations for residential surficial yard soils, as well as the mean background soils concentrations for rural northern Idaho. Figures A3.1 through A3.3 and Table A3.1 in Appendix A present additional summary statistics and distributions for mineral soil and soil litter lead concentrations since 1983. In general, soil litter (representing a highly variable thickness upper organic layer up to approximately 6 inches thick) contaminant levels are generally greater than the underlying surficial mineral soil contaminant concentrations (see Section 4.3.1 of the PD). Also, community mean soil contaminant levels generally decrease with increasing distance from the smelter facility.

5.1.2 House Dust Concentrations

Contaminant levels in interior house dusts are available from the 1974, 1975, 1983 and 1988 IDHW Health Surveys. Geometric mean concentrations for Smelterville, Kellogg/Wardner/Page and Pinehurst are used for evaluating chronic exposures for the typical population. Table 5.3 summarizes the means and extreme metals concentrations for house dusts in each of the communities. Figures A3.4 and A3.5 and Table A3.1 in Appendix A present additional summary statistics and distributions for house dusts since 1983. In general, the geometric means for the community mean house dust contaminant levels decrease with increasing distance from the smelter facility, a similar trend as exhibited by soils.

TABLE 5.2
GEOMETRIC MEAN AND EXTREME RESIDENTIAL SOIL METAL CONCENTRATIONS 1974, 1975, 1983 AND 1986/87 SURVEYS (μg/gm)

		As	Cd	Cu	Hg	Pb	Sb	Zn
1974								
Smelterville	Mean	7.9	55.0	-	14.4	6,141	111.0	1,920
	(95%ile)	(275.0)	(173.0)		(68.3)	(23,553)	(357.0)	(8,109)
Kellogg/Wardner/Page	Mean	35.0	19.3	-	4.1	2,514	32.1	1,228
	(95%ile)	(168.0)	(53.9)		(20.0)	(12,797)	(164.0)	(6,409)
Pinehurst	Mean	24.8	9.8	-	1.0	765	20.5	754
	(95%ile)	(143.0)	(31.7)		(4.0)	(4,443)	(171.0)	(3,075)
1975								
Smelterville	Mean	-	37.4	-	-	3,991	-	-
	(95%ile)		(205.0)			(25,565)		
Kellogg/Wardner/Page	Mean	-	20.7	-	-	2,586	-	-
	(95%ile)		(79.4)			(18,215)		
Pinehurst	Mean	-	6.9	-	-	508	-	-
	(95%ile)		(25.9)			(2,455)		
1983								
Smelterville	Mean	-	46.6	-	-	3,047	-	1,091
	(95%ile)		(194.0)			(29,912)		(5,039)
Kellogg/Wardner/Page	Mean	-	28.1	-	-	2,584	-	999
	(95%ile)		(84.4)			(14,257)		(3,291)
Pinehurst	Mean	-	9.7	-	-	472	-	410
	(95%ile)		(28.7)			(1,740)		(1,161)
1986/87								
Smelterville	Mean	52.0	33.0	87.0	4.2	2,685	10.9	774
	(95%ile)	(126.0)	(101.0)	(215.0)	(18.0)	(10,432)	(34.0)	(2,185)
Kellogg/Wardner/Page	Mean	45.1	17.6	71.0	2.6	1,988	8.9	705
	(95%ile)	(103.0)	(48.0)	(166.0)	(9.0)	(7,021)	(27.0)	(1,838)
Pinehurst	Mean	-	-	-	-	-	-	-
	(95%ile)							
Mean Background Rural Northern *Idaho (a)*		<10	0.8	28	0.1	43	1.1	95

\- Data not available. Exposure estimates will employ concentration from most recent measurements.

Sources: IDHW, 1974, 1975, 1983; and CH2M HILL, 1990a.
(a) Gott and Cathrall, 1980.

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5.1.4 Ambient Air Concentrations

Lead and total suspended particulate (TSP) monitoring has been conducted in the study area continuously since 1971 as part of the Idaho Air Quality Monitoring Network. Monitoring for airborne cadmium was conducted from 1973 through 1981. Quarterly mean air levels for lead and TSP for several air monitors located throughout the site are presented in Table 2.11. Concentrations for metals other than lead and cadmium are estimated using metal-to-lead ratios from a range of data sources. In general, metal-to-lead ratios were developed and applied for smelter pre-closure years and separate ratios for post-closure years for each of the communities using data from various studies (Ragaini et al., 1977; Cooper et al., 1981; Air Sciences, Inc., 1989). Annual mean and 24-hour maximum air metal concentrations are estimated for Smelterville, Kellogg/Wardner/Page and Pinehurst and summarized in Tables A3.2 and A3.3 in Appendix A. Annual mean air metal concentrations will be used to estimate chronic lifetime (baseline) exposures associated with inhalation in each of the residential communities. For those years in which pertinent data is lacking, most recent monitoring results and associated estimates were applied until new data became available. Some area estimates for post-closure copper, antimony and zinc were based on metal-to-lead ratios exhibited by surficial soils and soil litter. Greatest confidence in values presented in Tables A3.2 and A3.3 is associated with annual mean and 24-hour maximum concentrations for lead and cadmium as actual values.

5.2 Estimation of Intakes

USEPA guidance specifies that human population intake rate estimates be developed in order to quantify the potential health effects or risks associated with contaminant exposures. Estimated daily intakes for contaminants of concern are compared to published acceptable values. USEPA guidance suggests that in the absence of site-specific information standard assumptions regarding inhalation, ingestion, contact and absorption rates be applied to estimate human intakes. At the Bunker Hill site, previous epidemiological investigations have been conducted to assess the potential for adverse health effects associated with exposures to chemicals of concern and to characterize dose-response relationships for lead absorption in children. An assessment of existing information has been conducted to determine how these data can be used to develop intake and dosage estimates for critical exposure routes at this site (JEG et al., 1989). Section 7 of the PD develops and presents estimates for baseline and incremental intakes associated with chronic exposures to all contaminants of concern. An additional sub-chronic exposure evaluation for lead was also undertaken employing dose-response modeling to estimate the effects on childhood blood lead concentrations.

Estimation of human intakes for the contaminants of concern are a critical step in the determination of potential health effects of chemical exposures. The general equation used to estimate chemical chronic intakes by humans via a particular exposure route is:

$$
\begin{aligned}
CDI_r &= C \times HIF \\
&= \sum_i (C_i \times HIF_i / LT)
\end{aligned}
$$

where:

CDI_r	=	Route-specific Chronic Daily Intake, mg of chemical per kg body weight per day
C	=	Mean concentration, mg of chemical per unit of medium
HIF	=	Route and pathway specific Human Intake Factor (kg body weight per day)$^{-1}$
LT	=	Lifetime = 25,550 days (70 years); i = 1 to 25,550 days

Mean concentrations, C, at this site are derived from site monitoring data at each relevant exposure point and are found in the preceding section. Total chronic daily

TABLE 5.3

GEOMETRIC MEAN AND EXTREME HOUSE DUST METAL CONCENTRATIONS 1974, 1975, 1983 AND 1988 LEAD HEALTH SURVEY (μg/gm)

		As	Cd	Cu	Hg	Pb	Sb	Zn
1974								
Smelterville	Mean	8.0	113.0	-	17.8	10,583	185.0	5,432
	(95%ile)	(28.5)	(503.0)		(109.0)	(30,394)	(409.0)	(17,154)
Kellogg/Wardner/Page	Mean	5.7	65.5	-	7.3	6,581	174.0	3,940
	(95%ile)	(40.3)	(227.0)		(66.6)	(23,017)	(844.0)	(9,575)
Pinehurst	Mean	3.3	29.5	-	3.5	2,006	120.0	2,695
	(95%ile)	(15.9)	(73.5)		(11.9)	(5,453)	(312.0)	(6,515)
1975								
Smelterville	Mean	-	42.0	-	-	3,533	-	-
	(95%ile)		(159.0)			(21,807)		
Kellogg/Wardner/Page	Mean	-	44.7	-	-	4,573	-	-
	(95%ile)		(122.0)			(13,521)		
Pinehurst	Mean	-	25.0	-	-	1,749	-	-
	(95%ile)		(81.5)			(6,694)		
1983								
Smelterville	Mean	-	63.3	-	-	3,715	-	2,695
	(95%ile)		(123.5)			(7,754)		(5,070)
Kellogg/Wardner/Page	Mean	-	37.6	-	-	2,366	-	2,443
	(95%ile)		(93.0)			(7,840)		(10,373)
Pinehurst	Mean	-	24.6	-	-	1,155	-	1,578
	(95%ile)		(68.3)			(3,255)		(3,301)
1988								
Smelterville	Mean	25.7	15.4	177.0	1.3	1,203	18.9	1,394
	(95%ile)	(80.0)	(52.0)	(1,073.0)	(7.8)	(4,615)	(64.0)	(4,309)
Kellogg/Wardner/Page	Mean	26.3	15.6	167.0	1.3	1,450	27.9	1,401
	(95%ile)	(115.0)	(47.0)	(963.0)	(4.6)	(8,643)	(147.0)	(5,143)
Pinehurst	Mean	-	-	-	-	-	-	-
	(95%ile)							
Anaconda Smelter Site, Mill Creek, MT (a)		104-386	7-27			133-470		
Rural U.S. (b)						50-500		

- Data not available. Exposure estimates will employ concentration from most recent measurements.

Sources: IDHW 1974, 1975, 1983; and PHD, 1988.
(a) Clement Assoc., 1987.
(b) USEPA, 1989a.

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House dust contamination can be a result of the accumulation of windblown dusts from ore milling and smelting activities and from the redistribution or translocation of contaminated residential soils (see Section 4.3.2 of the PD). Comparison of the Bunker Hill mean soil and house dust lead concentrations for 1974 through 1983 indicates that mean house dust lead concentrations were approximately 1.4 times greater than mean residential yard soil lead concentrations. More recently, the ratio between mean house dust and soil lead concentrations at the site is observed to be approximately 1 (one) or less. This observation of house dust dependency on residential yard soil lead levels is consistent with results of other studies in industrial and urban areas (see Section 4.3.2 of the PD; USEPA, 1989a and b; ATSDR, 1988). In general, house dust contaminant levels reflect the levels observed in surficial yard soils.

5.1.3 Dietary Metal Concentrations

National market basket food concentration and intake data for the site contaminants of concern are developed from U.S. Food and Drug Administration sources (see Section 4.3.3 of the PD). Tables A5.1, A5.2 and A5.3 in Appendix A present National market basket metal daily intakes derived by the USFDA. Site tap water metal concentrations used to estimate daily intakes are from IDHW, Division of Health program files (see Section 4.3.3 of the PD). Concentrations of metals in local garden vegetables are available for cadmium, lead and zinc in carrots, beets and lettuce. Metals concentrations in local garden produce are used to evaluate exposures and consequent risk in an incremental analysis. Tables A5.4 and A5.5 in Appendix A summarize the available data for metals concentrations in local garden vegetables. Site groundwater concentrations used in a separate incremental exposure analysis are summarized in Table A5.6 in Appendix A.

intake, CDI, and total dosage, D, are determined as the sum of all route-specific intakes and dosages, respectively:

$$CDI = \sum_r CDI_r$$
$$D = \sum_r (CDI_r \times A_r)$$

where:

> A_r = route and media specific absorption/deposition rate; r = for all exposure routes. (Note that dosage is an absorbed amount which is also referred to as uptake).

Values for C may be developed in several ways. The USEPA (1988b and 1989g) recommends evaluating exposure based on both the best-estimates and the upper-bound estimates for environmental media concentrations. Only chronic exposures (versus sub-chronic) are evaluated at this site utilizing current USEPA guidances. Therefore, best estimates (geometric and arithmetic means) of environmental media concentrations for contaminants of concern will be used to evaluate typical or average exposures. This determination is based on the assumption that an individual is not expected to be exposed to upper-bound concentration levels for his or her entire lifetime. Extreme or upper-bound concentrations are evaluated as **incremental** and sub-chronic exposures. The evaluation of exposures to soils and dusts at extreme concentrations of contaminants is similar to the analyses performed as a reasonable maximum exposure (RME) under recent USEPA guidance (USEPA, 1989j). For the baseline analyses conducted here (representing the no-action remedial alternative), it is assumed that the concentrations of site contaminants are constant (do not degrade) and will not decrease with time from the most recent measurements.

The procedure for sub-chronic exposure characterization of lead employs the methodology described by the Environmental Criteria and Assessment Office (ECAO) of the USEPA, in the development of the *Air Quality Criteria Document* for lead (USEPA, 1986a) and the subsequent review by the Office of Air Quality Planning and Standards

(OAQPS) (USEPA, 1986c, 1988d, 1989e). This same method has also been used by the USEPA Office of Drinking Water and the Office of Solid Waste and Emergency Response to evaluate and predict the effects of lead in drinking water and contaminated soils, respectively, on human populations. This methodology constitutes the basis and rationale for USEPA health policy and standards regarding lead in environmental media. The analyses and evaluations conducted here for sub-chronic exposure and risk characterization of lead to children (a sensitive population to the effects of lead) are consistent with the approach and methodologies employed by the USEPA.

Human Intake Factor (HIF) values are required for estimating intakes for each of the receptor populations and exposure pathways. Variations in exposure factors, age and body weights are taken into account in the development of HIFs for specific subpopulations. Procedures for estimating human intakes under the current (since 1983) and historical (since 1971) exposure scenarios are identical. However, different concentrations of contaminants in environmental media are applied for estimating chemical intakes. Pre-1983 contaminant concentrations are not used in the current exposure scenario.

Human intake factors are derived from media mean intake rates and are age dependent. Intake rates are found in USEPA guidance documents and are presented and discussed in Section 7.1 of the PD. The following human intake parameters are used in the development of chronic HIFs:

Summary of Age Dependent Human Intake Parameters

Age (yr)	Body Wt (kg)	Inhalation Rate (m^3/day)	Total Soil/Dust Ingestion (mg/day)
0-1	10	5	100
2-6	17	5	100
7-12	35	10	100
13-17	55	20	100
18-70	70	20	100

Determination of time correction and media partition factors for use in the derivation of HIFs for this site take into consideration site-specific data obtained during area health surveys. The primary media partition factor (MPF) required for this analysis incorporates time correction factors (TCFs) from daily indoor versus outdoor activity assessments. Three primary source categories represent exposures in the home to interior house dust, direct contact exposures to soil in residential yards, and exposures to other soils and fugitive dust in the neighborhood or community. Various analyses were conducted and discussed in Section 4 and 7 of the PD and are summarized as follows:

Estimates of Indoor:Outdoor Exposure and Source Partition Ratios
(for Preschool Children)

Source of Estimate	Indoor:Outdoor	Exposure Period
Exposure Factors Handbook (USEPA, 1989g)	78 : 22	Annual Average
OAQPS Model Input (USEPA, 1989e)	75 : 25	Annual Average
Activity Weighted TCFs (JEG et al., 1989)	77 : 23 53 : 47	Annual Average Summer Months
Parental Interviews, 1983 Lead Health Survey	60 : 40	Summer Months
Partition Analysis of Blood Lead Response, 1983 (JEG et al., 1989)	40 : 60	Summer Months

General equations for determination of route-specific HIFs used in the chronic exposure evaluation are presented in Table 5.4. HIF values developed using the above intake parameters and MPFs are summarized in Tables 5.5 and 5.6.

Table 5.4
Equations for Calculating HIF Values for Specific Pathways

Route	Medium	Human Intake Factor
Oral	Water	$HIF = \frac{WI \times (TCF/MPF)}{BW}$
	Food	$HIF = \frac{FI \times (TCF/MPF)}{BW}$
	Soil	$HIF = \frac{SI \times (TCF/MPF)}{BW}$
	Dust	$HIF = \frac{DI \times (TCF/MPF)}{BW}$
Inhalation	Airborne Particulates	$HIF = \frac{SP \times VR \times (TCF/MPF)}{BW}$

where:

HIF =	Human intake factor, units vary by exposure route
BW =	Body weight, kg
TCF/MPF =	Time correction factor or media partition factor (unitless)
WI =	Water intake, L/day
FI =	Food intake, kg/day
SI =	Soil intake, kg/day
DI =	Dust intake, kg/day
VR =	Ventilation rate, m^3/day
SP =	Suspended particulate concentration in air, kg/m^3

Table 5.5
Summary of Baseline Human Intake Factors

Medium	Age	Value
Air (m^3/kg/day)	0-1	0.5
	2-6	0.29
	7-12	0.29
	13-17	0.57
	18-70	0.29
Residential Soil (kg/kg/day)	0-1	1.0×10^{-6}
	2-6	1.0×10^{-6}
	7-12	7.1×10^{-7}
	13-17	6.0×10^{-7}
	18-70	2.0×10^{-7}
House Dust (kg/kg/day)	0-1	8.7×10^{-6}
	2-6	4.4×10^{-6}
	7-12	1.6×10^{-6}
	13-17	1.7×10^{-6}
	18-70	1.2×10^{-6}
Other Soil/Dust (kg/kg/day)	0-1	3.0×10^{-7}
	2-6	4.1×10^{-7}
	7-12	5.4×10^{-7}
	13-17	6.0×10^{-7}
	18-70	2.9×10^{-8}
Drinking Water (L/kg/day)	All[(a)]	3.6×10^{-2}
Market Basket	-[(b)]	

(a) This is a time-weighted HIF.
(b) HIFs are not applicable to ingestion of market basket foods. Direct market basket foods intakes are derived.

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Table 5.6
Summary of Human Intake Factors for Calculation of Incremental Intakes

Increment	Age	HIF (kg/kg/day)
Extreme Ingestion:		
Residential Soil[(a)]	2-6	9.1×10^{-6}
House Dust[(a)]	2-6	4.0×10^{-5}
Other Soil/Dust[(a)]	2-6	3.9×10^{-6}
Other Soil/Dust[(b)]		--
Water[(b)]		--
Fish Ingestion[(c)]		--
Local Vegetable Ingestion[(d)]		--

(a) Extreme soil/dust ingestion HIFs are for the ages 2-6 only. This behavior describes what is typically known as "pica" behavior. The HIF values represent the incremental increase in ingestion (+ 900 mg) over baseline ingestion rates. This HIF was used in the calculation of TWA lifetime intake over 70 years.
(b) HIFs for Other Soil/Dust and Drinking Water increments are the same as those used for the baseline (Table 5.5).
(c) HIFs not applicable to fish ingestion increment. Incremental intakes of chemicals calculated directly from available data (see Table 5.9).
(d) HIFs not applicable to local vegetable (garden) produce increment. Incremental intakes of chemicals calculated from available data (see Table 5.8).

5.2.1 Inhaled Air

Historical and current human intakes associated with inhaled air are determined using air data presented in Table A3.2 of Appendix A and the age-specific HIFs in Table 5.5. For example, for a 2-year-old in Kellogg in 1973 the specific intake for lead is estimated to be:

$$\text{Intake}_{(\text{air})} = \text{Concentration}_{(\text{air})} \times \text{HIF}_{(\text{inhalation})} = 1.5 \times 10^{-2}\ \text{mg/m}^3 \times 0.29\ \text{m}^3\text{/kg/day}$$
$$= 4.35 \times 10^{-3}\ \text{mg/kg/day} \quad \text{for lead}$$

Annual mean intakes are calculated and presented in intake tables found in Attachment 1 of Appendix A7 of the PD. Annual intakes are averaged over a 70-year lifetime in order to determine chronic daily lifetime mean intake, which is estimated to be 4.28×10^{-4} mg/kg/day in the case of lead via inhalation for the historical scenario in Kellogg.

5.2.2 Food and Beverage

5.2.2.1 Drinking Water

None of the public water supplies in the RI/FS area, sampled November 1976 through June 1985, have been reported to exceed the National Drinking Water Standards for As, Cd, Pb or Hg (IDHW, 1976-1985). Actual concentrations in public water supplies in the study area have generally shown levels less than analytical quantitation limits. For the baseline exposure assessment, intake estimates from local drinking water sources will be at concentrations representing arithmetic means of IDHW monitoring results, generally at method quantitation limits. These intake estimates are expected to represent upper limits for contaminant intakes associated with the consumption of public drinking water.

An estimation of metal intakes associated with potential groundwater consumption is accomplished in order to evaluate incremental intakes and consequent risk. Metal concentrations for rural northern Idaho background are also substituted for comparison to site intakes. Estimates of metal intake from water consumption are presented in Table 5.7.

5.2.2.2 National Market Basket Foods

The contribution of the average diet to contaminant intakes in the exposure assessment is evaluated by incorporating national market basket survey results from the U.S. Food and Drug Administration. Detailed presentation and discussion is provided in Section 7.1.4.2 of the PD. Age-specific metal intake rates summarized in Tables A5.1, A5.2 and A5.3 of Appendix A are for food and beverages only and do not include water intakes.

Recent information (USEPA, 1990b) indicates that dietary lead intakes have continued to decrease relative to the levels presented in the PD due to further reductions in dietary lead content. Lead levels in food have been declining due to decreased emissions from automobile and point sources, lower lead levels in water, and less use of lead soldered food containers. National average daily dietary lead intake from FDA total diet studies for 1980 through 1989 are as follows:

National Average Daily Dietary Lead Intake (μg/day)
(from USEPA, 1990b)

Age	1980	81/82	82/84	84/86	86/88	88/89
6-month-old	34	20	17	10.1	4.1	4.8
2-year-old	43	30	23	13.3	5.3	5.0

5.2.2.3 Locally Grown/Acquired Produce

Locally grown garden produce could have significant impact on metal intakes. A number of local gardens were sampled during the 1983 Lead Health Survey, and survey participants were questioned as to their use of local produce. A summary of the results

Table 5.7
Estimates of Metal Intake from Water Consumption(a)

Metal	Current Drinking Water, Background		Kellogg Groundwater		Smelterville Groundwater	
	Conc. mg/L	CDI mg/kg/day	Conc. mg/L	CDI mg/kg/day	Conc. mg/L	CDI mg/kg/day
Sb	-(b)		0.05	1.8×10^{-3}	0.05	1.8×10^{-3}
As	0.0015	5.4×10^{-5}	0.005	1.8×10^{-4}	0.014	5.0×10^{-4}
Cd	0.006 0.002*	2.2×10^{-4} 7.2×10^{-5}	0.038	1.4×10^{-3}	0.247	8.9×10^{-3}
Cu	--		--		--	
Pb	0.0085	3.1×10^{-4}	0.081	2.9×10^{-3}	0.175	6.3×10^{-3}
Hg	0.0002	7.2×10^{-6}	0.0002	7.2×10^{-6}	0.0002	7.2×10^{-6}
Zn	0.81 2.24*	2.9×10^{-2} 8.1×10^{-2}	8.38	0.30	11.9	0.43

(a) Concentration data from Table A5.6.
CDI = Concentration (mg/L) x 3.6×10^{-2} (L/kg/day).
HIF from Table 5.5.
(b) No data available.
* Tap water concentration from IDHW, 1976-1985.
All other background concentrations from Parliman et al., 1980.
Chronic Daily Incremental Intake = CDI (Groundwater) - CDI (Background).

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of that survey are found in other site documents (PHD et al., 1986; JEG et al., 1989). Vegetable metal concentrations, consumption rates, and consequent metal intakes are developed in Section 7 of the PD and summarized in Table 5.8. Intake estimates for site produce are assumed to occur for a period of 90 days when garden produce is available. Both total and incremental annual intakes in Table 5.8 represent 90 days of local produce consumption plus the remainder of the year utilizing national market basket produce. Sub-chronic intakes of lead, for example, due to a full diet of local vegetable consumption could account for greater than 200 times as much metal as that resulting from market basket vegetable consumption.

Sub-chronic metal intakes associated with consumption of local garden vegetables are significant. Mean metal intakes resulting from consumption of locally grown vegetables are calculated and are considered as additional intakes in an **incremental** exposure analysis. Routine consumption of locally grown produce could result in an additional sub-chronic intake of up to 480 µg/day of dietary lead for adults and pregnant women during three months of the year.

An evaluation of potential metal intakes associated with local fish (from the area around Lake Coeur d'Alene) consumption is discussed in Section 7.1.4.3 of the PD. A summary of metal intakes associated with fish consumption is found in Table 5.9. Local area fish consumption will be evaluated as an incremental intake.

5.2.3 Soils and Dusts

Metal in dust and soil results from a complex mixture of naturally occurring fine soil particles, smelting and/or mining wastes, flaked paints, and deposited airborne particles from industrial and/or automotive origin. Children are exposed to soils and surface dust in their homes and yards, in neighborhood locations where they play, at child care facilities, at designated playgrounds, schools and parks, as they walk to activity centers or visit neighbors. Sources that have previously been identified in this area are house dusts,

Table 5.8
Estimates of Metal Intake from Vegetable Consumption

	Vegetable Consumption Rate, gm/day		Wet Weight Metal Conc., μg/gm		Mean Intake μg/day				
	Leafy	Root	Leafy	Root	Leafy	Root	Total Intake, μg/day	Annual Average Incremental Intake, μg/day	Annual Average Total Intake, μg/day
SMELTERVILLE/KELLOGG									
Pb Child (2-6 yr.)	25	15	6.1	4.5	153	68	220	55	56
Adult	55	33			336	149	484	120	123
Cd Child (2-6 yr.)	25	15	1.8	1.5	45	23	68	17	18
Adult	55	33			99	50	149	37	39
Zn Child (2-6 yr.)	25	15	27.5	29.2	688	438	1126	259	347
Adult	55	33			1513	964	2476	561	764
PINEHURST									
Pb Child (2-6 yr.)	25	15	3.5	2.2	88	33	121	30	31
Adult	55	33			193	73	265	66	68
Cd Child (2-6 yr.)	25	15	0.45	1.2	11	18	29	7	8
Adult	55	33			25	40	64	16	18
Zn Child (2-6 yr.)	25	15	27.7	14.7	693	221	913	206	294
Adult	55	33			1524	485	2009	454	647
NATIONAL MARKET BASKET									
Pb Child (2-6 yr.)	25	15	0.017	0.041	0.43	0.62	1.0	--	1.0
Adult	55	33			0.94	1.35	2.3	--	2.3
Cd Child (2-6 yr.)	25	15	0.033	0.016	0.83	0.24	1.1	--	1.1
Adult	55	33			1.82	0.53	2.3	--	2.3
Zn Child (2-6 yr.)	25	15	2.26	2.10	56.5	31.5	88	--	88
Adult	55	33			124	69.3	194	--	194

DI for Child (mg/kg/day) = Intake (μg/day) x (5.9×10^{-5})
DI for Adult (mg/kg/day) = Intake (μg/day) x (1.4×10^{-5})

Time-Weighted Averaged Intake (CDI) = (Child DI x 5/69) + (Adult DI x 64/69)

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Table 5.9
Incremental Daily Intakes for Consumption of Local Fish[a]

Metal	Individual	HIF, kg/kg/day	Fish Tissue Conc., mg/kg[b]	Intake, mg/kg/day	Incremental Intake, mg/kg/day[f]
Site Population					
Cd	Child (2-6 yr.)	1.2×10^{-3}[c]	0.094	1.1×10^{-4}	9.1×10^{-5}
	Adult	6.9×10^{-4}[d]	0.094	6.5×10^{-5}	5.4×10^{-5}
Pb	Child (2-6 yr.)	1.2×10^{-3}	0.45	5.4×10^{-4}	4.7×10^{-4}
	Adult	6.9×10^{-4}	0.45	3.1×10^{-4}	2.7×10^{-4}
Market Basket (moderate consumption rate)[e]					
Cd	Child (2-6 yr.)	1.2×10^{-3}	0.016	1.9×10^{-5}	
	Adult	6.9×10^{-4}	0.016	1.1×10^{-5}	
Pb	Child (2-6 yr.)	1.2×10^{-3}	0.055	6.6×10^{-5}	
	Adult	6.9×10^{-4}	0.055	3.8×10^{-5}	

(a) Source: ATSDR,1986.

(b) Geometric mean concentrations.

(c) 2 fish meals/wk. (moderate consumption) x 70 gm/meal x 1 wk/7 days x 1/17 kg x kg/1000 gm = 1.2×10^{-3} kg/kg/day.

(d) 2 fish meals/wk. (moderate consumption) x 170 gm/meal x 1 wk/7 days x 1/70 kg x kg/1000 gm = 6.9×10^{-4} kg/kg/day.

(e) Market Basket fish concentration data from: USFDA, 1988.

(f) Incremental Intake = Intake (Site Population) - Intake (Market Basket).
Time-Weighted Average Intake (CDI) = (Child Intake x 5/69) + (Adult Intake x 64/69).

residential surficial yard soils, road dusts, playground soils, windblown dusts, and dusts of industrial or occupational origin.

Estimation of metal intake rates from incidental ingestion of soil and dust requires:

- Determination of an overall ingestion rate for soils and dusts,
- Partitioning the total ingestion rate by the source categories using the pertinent MPFs (in terms of the indoor:outdoor partition ratios for dusts and soils, respectively, presented above), and
- Multiplying each of the partitioned ingestion rates by the metal-media concentration representative of that category.

Representative concentrations for metals in each of the communities for the site are found in Table 5.2 for residential soils and Table 5.3 for house dusts.

Estimates for overall soil/dust ingestion rates are available from both the literature and current guidance, and can be derived from an analysis of site-specific data. The "Exposure Factors Handbook" (USEPA, 1989g) and the "OAQPS Review of NAAQS" (USEPA, 1989d and e) include comprehensive reviews of pertinent studies. Overall soil and dust ingestion rates range from 55 to approximately 600 mg/day (Hawley, 1985; Kimbrough et al., 1984; Binder et al., 1986; Clausing et al., 1987; and Sedman, 1989). Binder et al. suggests a total ingestion rate of 180 mg/day and is based on trace metal mass balances in toddler stool samples conducted near an active lead smelter in East Helena, Montana. The AQCD (USEPA, 1986a) uses a total soil and dust mean ingestion rate of 90 mg/day as a consensus value in evaluating various sources of lead to young children.

A detailed discussion regarding soil and dust ingestion rates is presented in Section 7.1.5 of the PD. In summary, a typical childhood ingestion rate of soil and dust ranges from 50 to 200 mg/day. Site-specific analyses for the average child at Bunker Hill support the lower end of this range. However, this result is dependent on assumptions regarding lead gastrointestinal absorption rates (JEG et al., 1989; see Appendix C). Lifetime chronic exposures to soil/dust (combined) are evaluated here at 100 mg/day for the average population, and 1,000 mg/day for "pica-type" behavior during ages 2-6 years in an incremental analysis.

Metal intakes from residential soil and house dust ingestion for children 2-6 years of age in Smelterville and Kellogg/Wardner/Page are estimated for 1983 and 1986-88 and presented in Table 5.10. Table 5.10 presents a range of intakes using two different partition ratios to show how intake estimates can vary for the two different media (house dusts versus soils). However, the total metal intake for soil/dust is minimally affected by differences in the partition ratio for soils and dusts. Because house dust metal levels are dependent on residential soils, the range of total metal intakes expressed in Table 5.10 are ultimately based on residential yard soil metal concentrations. Estimation of annual and mean chronic intakes due to soil and dust exposures using age-specific MPFs are presented in Attachment 1 of Appendix A7 in the PD.

5.2.4 Integration of Contaminant Intakes from Multiple Exposure Routes

Each exposure route and its associated contaminant intake is summed to determine total intake for each of the contaminants of concern. The total integrated intakes for each contaminant are subsequently used in the risk evaluation for comparison to critical toxicity values, such as acceptable chronic daily intake values and cancer potency factors. All of the route-specific **baseline** intakes presented above and in the PD are summarized in Table 5.11. Intake estimates for the historical and current scenarios are compared to background intakes in Table 5.12. The relative contributions of each of the route-specific intakes to the total intake are presented as percent relative contributions in Table 5.13. A summary of the **incremental** chronic daily contaminant intakes for five potentially high risk activities evaluated above is presented in Table 5.14. A comparison of each of the

Table 5.10 (Page 1 of 2)
Mean Daily Metal Intakes from Soil and Dust
for Children 2-6 Years of Age[(a)]

		Mean Conc. (μg/gm)		Residential Soil Intake (μg/day)		House Dust Intake (μg/day)		Total Intake from Soil/Dust (μg/day)	
		Soil	House Dust	Typical	Extreme	Typical	Extreme	Typical	Extreme
Smelterville									
Sb	1983								
	1986/88	10.9	18.9	0.3-0.7	2.7-6.5	0.8-1.4	7.6-14.1	1.5-1.7	14-17
As	1983								
	1986/88	52	25.7	1.3-3.1	13-31	1.0-1.9	10-19.2	3.2-4.1	32-41
Cd	1983	46.6	63.3	1.2-2.8	12-28	2.5-4.7	25-47.5	5.3-5.9	53-60
	1986/88	33.0	15.4	0.8-2.0	8.3-20	0.6-1.2	6.2-11.6	2.0-2.6	20-26
Cu	1983								
	1986/88	87	177	2.2-5.2	22-52	7.1-13.3	71-133	12-16	123-155
Pb	1983	3047	3715	76-183	762-1830	149-280	1490-2790	332-356	3320-3550
	1986/88	2685	1203	67-161	671-1610	48-90	481-902	157-209	1570-2090
Hg	1983								
	1986/88	4.2	1.3	0.1-0.3	1.1-2.5	0.05-0.1	0.5-1.0	0.2-0.4	2.1-3.0
Zn	1983	1091	2695	27-65	273-655	108-202	1080-2020	173-229	1740-2290
	1986/88	774	1394	19-46	194-464	56-105	558-1050	102-124	1020-1240
Kellogg/Wardner/Page									
Sb	1983								
	1986/88	8.9	27.9	0.2-0.5	2.2-5.3	1.1-2.1	11-20.9	1.6-2.3	16-23
As	1983								
	1986/88	45.1	26.3	1.1-2.7	11-27	1.1-2.0	11-19.7	3.1-3.8	31-38
Cd	1983	28.1	37.6	0.7-1.7	7.0-16.9	1.5-2.8	15-28.2	3.2-3.5	32-35
	1986/88	17.6	15.6	0.4-1.1	4.4-10.6	0.6-1.2	6.2-11.7	1.6-1.7	16-17
Cu	1983								
	1986/88	71	167	1.8-4.3	17.8-43	6.7-12.5	67-125	11-14.3	110-143
Pb	1983	2584	2366	65-155	646-1550	95-177	946-1770	242-250	2420-2500
	1986/88	1988	1450	50-119	497-1190	58-109	580-1090	159-177	1590-1770
Hg	1983								
	1986/88	2.6	1.3	0.07-0.2	0.7-1.6	0.05-0.1	0.5-1.0	0.17-0.25	1.7-2.1
Zn	1983	999	2443	25-60	250-599	98-183	977-1830	158-208	1580-2080
	1986/88	705	1401	18-42	176-423	56-105	560-1050	98-123	980-1230
Pinehurst									
Sb	1983								
	1989/90	8	(8)	0.2-0.5	2.0-4.8	(0.3-0.6)	(3.2-6.0)	(0.8)	(8.0)
As	1983								
	1989/90	23	(23)	0.6-1.4	5.8-14	(0.9-1.7)	(9.2-17)	(2.3)	(23)
Cd	1983	9.7	24.6	0.2-0.6	2.4-5.8	1.0-1.8	9.8-19	3.0-6.0	16-21
	1989/90	5	(5)	0.1-0.3	1.3-3.0	(0.2-0.4)	(2.0-3.8)	(0.5)	(5.0)

Table 5.10 (Page 2 of 2)
Mean Daily Metal Intakes from Soil and Dust
for Children 2-6 Years of Age[(a)]

		Mean Conc. (µg/gm)		Residential Soil Intake (µg/day)		House Dust Intake (µg/day)		Total Intake from Soil/Dust (µg/day)	
		Soil	House Dust	Typical	Extreme	Typical	Extreme	Typical	Extreme
Cu	1983								
	1989/90	39	(39)	1.0-2.3	9.8-23	(1.6-2.9)	(16-29)	(3.9)	(39)
Pb	1983	472	1155	12-28	118-283	46-87	462-866	74-99	745-984
	1989/90	463	(463)	12-28	115-278	(19-35)	(185-347)	(47)	(463)
Hg	1983								
	1989/90	0.4	(0.4)	0.01-0.02	0.1-0.2	(0.02-0.03)	(0.2-0.3)	(0.04)	(0.4)
Zn	1983	410	1578	10-25	103-246	63-118	631-1180	88-128	877-1280
	1989/90	389	(389)	9.7-23	97-233	(16-29)	(156-292)	(39)	(389)

Note: House dust concentrations and intakes in parentheses are estimates assuming house dust levels to be equivalent to residential soils, since actual data are currently not available.

(a) Media concentrations from Section 2 and Protocol document Section 4.0. Typical ingestion rate for soil/dust is 100 mg/day and extreme rate is 2,000 mg/day due to "pica-type" behavior; soil:dust partition (TCF) is presented as a range where (25-60):(75-40) represents the time-weighted ratios presented in Section 5.2 for the OAQPS Model Input and the Blood Lead Response Partition Analysis, respectively. For example, the HIFs employed using the OAQPS Model Input parameters are:

typical, soil = 1.4×10^{-6} kg/kg/day
typical, house dust = 4.4×10^{-6} kg/kg/day
extreme, soil = 1.4×10^{-5} kg/kg/day
extreme, house dust = 4.4×10^{-5} kg/kg/day

Intake (µg/day) = media concentration (mg/kg) x HIF x body weight (kg) x 10 µg/mg.

BOIT793/028.51/tlm

Table 5.11 (from Protocol document) (Page 1 of 2)
Summary of Chronic Route-Specific Intakes (mg/kg/day)
(All Values are 10^{-6})

			Route-Specific Intake							
Scenario	Location	Contaminant	Inhalation	Yard Soil Ingestion	House Dust Ingestion	Other Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral	Total All Routes
Historical	Smelterville	Arsenic	9.5	22.4	30.7	10.4	54	700	818	827
		Cadmium	22.6	13.2	57.9	5.85	72	350	499	522
		Lead	441	1240	4770	549	310	990	7860	8300
		Zinc	352	440	3570	212	81000	290	85500	85900
		Antimony[a]	10.2	21	109	12.1	--	140	282	292
		Mercury[b]	--	3.09	7.89	1.63	7.2	50	69.8	69.8
		Copper[a]	36.1	29.7	284	12.6	--	--	326	363
	Kellogg/ Wardner/Page	Arsenic	14.1	13.6	29.7	5.45	54	700	803	817
		Cadmium	18.7	6.72	42.4	3.06	72	350	470	493
		Lead	428	776	4330	349	310	990	6760	7180
		Zinc	192	323	3050	151	81000	290	84800	85000
		Antimony	6.6	7.03	115	3.73	--	140	266	272
		Mercury	--	1.19	3.94	0.540	7.2	50	62.9	62.9
		Copper	43.8	24.2	268	10.3	--	--	303	346
	Pinehurst	Arsenic	3.36	8.52	4.82	3.62	54	700	771	774
		Cadmium	11.1	3.14	41.9	1.27	72	350	468	479
		Lead	222	181	2280	76.8	310	990	3840	4060
		Zinc	22.9	190	3100	86.8	81000	290	84700	84700
		Antimony	3.36	7.16	193	3.04	--	140	343	347
		Mercury	--	0.341	3.10	0.145	7.2	50	60.8	60.8
		Copper	3.92	--	--	--	--	--	--	--
Current	Smelterville	Arsenic	5.19	18.9	38.1	7.95	54	570	689	694
		Cadmium	9.44	11.8	42.1	5.00	72	230	361	370
		Lead	110	931	2880	394	310	670	5190	5300
		Zinc	70.3	277	2730	117	81000	220	84300	84400
		Antimony	4.97	8.04	54	3.19	--	77	142	147
		Mercury	--	1.79	7.99	0.739	7.2	52	69.7	69.7
		Copper	34.2	29.7	284	12.6	--	19	345	379
	Kellogg/ Wardner/Page	Arsenic	2.54	14.9	38.5	6.35	54	570	684	686
		Cadmium	2.91	6.56	34	2.76	72	230	345	348
		Lead	35.7	703	2670	297	310	670	4650	4690
		Zinc	25.5	253	2640	107	81000	220	84200	84200
		Antimony	1.27	4.05	65.6	1.67	--	77	148	150
		Mercury	--	1.07	3.86	0.450	7.2	52	64.6	6.46
		Copper	43.8	24.2	268	10.3	--	19	322	365

Table 5.11 (from Protocol document) (Page 2 of 2)
Summary of Chronic Route-Specific Intakes (mg/kg/day)
(All Values are 10^{-6})

Scenario	Location	Contaminant	Inhalation	Yard Soil Ingestion	House Dust Ingestion	Other Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral	Total All Routes
			Route-Specific Intake							
	Pinehurst	Arsenic	0.313	8.52	4.82	3.62	54	570	641	641
		Cadmium	2.25	3.41	40.1	1.45	72	230	347	349
		Lead	25.7	161	1850	68.3	310	670	3060	3090
		Zinc	7.55	140	2530	59.3	81000	220	83900	84000
		Antimony	0.313	7.16	193	3.04	--	77	280	281
		Mercury	--	0.341	5.62	0.145	7.2	52	65.3	65.3
		Copper	0.340	--	--	--	--	19	--	--
Background	All	Arsenic	0.313	3.41	16.1	1.45	54	570	645	645
		Cadmium	0.939	0.273	1.28	0.116	72	230	304	305
		Lead[(c)]	14.1	14.7	442 [69]	6.22	310	670	1440 [1070]	1460 [1080]
		Zinc	7.51	32.4	153	13.7	81000	220	81400	81400
		Antimony[(a)]	0.313	0.375	1.77	0.159	--	77	79.3	79.6
		Mercury[(b)]	--	0.0341	0.161	0.0145	7.2	52	59.4	59.4
		Copper[(a)]	0.313	9.54	45	4.05	--	19	77.6	77.9

(a) No antimony or copper data are available for drinking water.
(b) No background air data are available for mercury.
(c) [Value] is relative to background soil concentration; 43 μg/gm Pb.

Table 5.12 (from Protocol document)
Comparison of Chronic Lead Intakes (as ratios)
by Location and Scenario[(a)]

Location	Route	Historical: Background	Current: Background	Historical: Current
Smelterville	Inhalation	31.3	7.8	4.0
	Yard Soil Ingestion	84.4	63.3	1.3
	House Dust Ingestion[(b)]	10.8	6.5	1.7
		[69.1]	[41.7]	
	Other Soil/Dust Ingestion	88.3	63.3	1.4
	Drinking Water	1.0	1.0	1.0
	Market Basket Food	1.0	1.0	1.5
	Total Oral(b)	5.5	3.6	1.5
		[7.3]	[4.9]	
	All Routes[(b)]	5.7	3.6	1.6
		[7.7]	[4.9]	
Kellogg/Wardner/ Page	Inhalation	30.4	2.5	12.0
	Yard Soil Ingestion	52.8	47.8	1.1
	House Dust Ingestion[(b)]	9.8	6.0	1.6
		[62.8]	[38.7]	
	Other Soil/Dust Ingestion	56.1	47.7	1.4
	Drinking Water	1.0	1.0	1.0
	Market Basket Food	1.0	1.0	1.5
	Total Oral(b)	4.7	3.2	1.5
		[6.3]	[4.3]	
	All Routes[(b)]	4.9	3.2	1.5
		[6.6]	[4.3]	
Pinehurst	Inhalation	15.7	1.8	8.6
	Yard Soil Ingestion	12.3	11.0	1.1
	House Dust Ingestion[(b)]	5.2	4.2	1.2
		[33.0]	[26.8]	
	Other Soil/Dust Ingestion	12.3	11.0	1.1
	Drinking Water	1.0	1.0	1.0
	Market Basket Food	1.0	1.0	1.5
	Total Oral(b)	2.7	2.1	1.3
		[3.6]	[2.9]	
	All Routes(b)	2.8	2.1	1.3
		[3.8]	[2.9]	

(a) All summary intake estimates are from Table 5.11.
(b) [Ratio] is relative to background soil concentration; 43 ppm Pb.
Nonbracketed value is relative to mean national house dust concentration for Pb; 275 ppm.

Table 5.13 (from Protocol document)
Summary of Chronic Route-Specific Intakes
as a Percentage of Total Intake

Scenario	Location	Contaminant	Percentage Total Oral Intake, %					Percentage intake all routes, %	
			Yard Soil Ingestion	House Dust Ingestion	Other Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral	Inhalation
Historical	Smelterville	Arsenic	2.7	3.8	1.3	6.6	85.6	98.9	1.1
		Cadmium	2.6	11.6	1.2	14.4	70.2	95.6	4.4
		Lead	15.8	60.7	7.0	3.9	12.6	94.7	5.3
		Zinc	0.5	4.2	0.2	94.7	0.4	99.5	0.5
		Antimony(a)	7.4	38.7	4.3	--	49.6	96.6	3.4
		Mercury(b)	4.4	11.3	2.3	10.3	71.7	--	--
		Copper(a)	9.1	87.1	3.8	--	--	89.8	10.2
	Kellogg/ Wardner/ Page	Arsenic	1.7	3.7	0.7	6.7	87.2	98.3	1.7
		Cadmium	1.4	8.9	0.6	15.2	73.8	96.1	3.9
		Lead	11.5	64.1	5.2	4.6	14.6	94.2	5.8
		Zinc	0.4	3.6	0.2	95.5	0.3	99.8	0.2
		Antimony	2.6	43.2	1.4	--	52.8	97.8	2.2
		Mercury	1.9	6.2	0.9	1.1	89.9	--	--
		Copper	8.0	88.4	3.4	--	--	87.6	12.4
	Pinehurst	Arsenic	0.7	0.6	0.5	7.0	91.2	99.6	0.4
		Cadmium	0.7	9.0	0.3	15.4	74.6	97.7	2.3
		Lead	4.7	59.4	2.0	8.1	25.8	94.6	5.4
		Zinc	0.2	3.6	1.0	95.6	0.3	-100.0	-0
		Antimony	2.1	56.3	0.9	--	40.7	98.8	1.2
		Mercury	0.6	5.1	0.2	11.8	82.3	--	--
		Copper	--	--	--	--	--	--	--
Current	Smelterville	Arsenic	2.7	5.5	1.2	7.8	82.8	99.3	0.7
		Cadmium	3.3	11.7	1.4	19.9	63.7	97.6	2.4
		Lead	17.9	55.5	7.6	6.0	13.0	97.9	2.1
		Zinc	0.3	3.2	0.1	96.1	0.3	99.9	0.1
		Antimony	5.6	38.0	2.2	--	54.2	96.6	3.4
		Mercury	2.6	11.5	1.0	10.3	74.6	--	--
		Copper	8.6	82.3	3.7	--	5.4	91.0	9.0
	Kellogg/ Wardner/ Page	Arsenic	2.2	5.6	0.9	7.9	83.4	99.7	0.3
		Cadmium	1.9	9.9	0.8	20.9	66.5	99.1	0.9
		Lead	15.1	57.4	6.4	6.7	14.4	99.1	0.9
		Zinc	0.3	3.1	0.1	96.2	0.3	-100.0	-0
		Antimony	2.7	44.3	1.1	--	51.9	98.7	1.3
		Mercury	1.7	6.0	0.7	11.1	80.5	--	--
		Copper	7.5	83.2	3.2	--	6.1	88.2	11.8
	Pinehurst	Arsenic	1.3	0.8	0.6	8.4	88.9	-100.0	-0
		Cadmium	1.0	11.6	0.4	20.7	66.3	99.4	0.6
		Lead	5.3	60.5	2.2	10.1	21.9	99.0	1.0
		Zinc	0.1	2.9	0.6	96.4	0.2	99.9	0.1
		Antimony	2.6	68.9	1.1	--	27.4	99.6	0.4
		Mercury	0.5	8.6	0.2	11.0	79.7	--	--
		Copper	--	--	--	--	--	--	--
Back-ground	All	Arsenic	0.5	2.5	0.2	8.4	88.4	-100.0	-0
		Cadmium	0.1	1.4	-0	23.7	75.8	99.7	0.3
		Lead(c)	1.0	30.7	0.4	21.5	46.4	98.6	1.4
			[1.4]	[6.4]	[0.6]	[29.0]	[62.6]	[99.1]	[0.9]
		Zinc	-0	0.2	-0	99.5	0.3	-100.0	-0
		Antimony(a)	0.5	2.2	0.2	--	97.1	99.6	0.4
		Mercury(b)	-0	0.3	-0	12.1	87.6	--	--
		Copper(a)	12.3	58.0	5.2	--	24.5	99.6	0.4

(a) No antimony or copper data are available for drinking water.
(b) No background air data are available for mercury.
(c) [%] is relative to background soil concentration; 43 ppm Pb.
Nonbracketed value is relative to mean national house dust concentration for Pb; 275 ppm.

incremental intakes to the total baseline intake is presented in Table 5.15 as percent additional increases above total baseline intakes for each contaminant.

5.3 Chronic Exposures

For **arsenic**, the bulk of the baseline chronic exposures/intakes in Table 5.11 is associated with market basket food for all scenarios and locations, with the greatest estimated total intake in Kellogg/Wardner/Page during the historical scenario at approximately 27% greater intake than for off-site background exposures. Greatest intakes due to inhalation are also found in Kellogg/Wardner/Page during the historical scenario at approximately 45 times greater intake than for off-site background exposures. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15.

The additional exposures/intakes in Table 5.14 are presented so that intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for arsenic can yield an increased intake above background of 9% to 106% for current (since 1983) Pinehurst and historical (since 1971) Smelterville, respectively. These are determined by comparison of "Total All Intakes" in Table 5.14 to "Total All Routes" for background in Table 5.11. For example, in the case of historical Smelterville for arsenic:

$$106\% = 100 \times (1330 - 645) \times 10^{-6}/(645 \times 10^{-6})$$

The largest chronic intake increments are associated with groundwater consumption and extreme soil/dust consumption (due to "pica-type" behavior).

Baseline **cadmium** exposures/intakes are primarily from market basket food, drinking water, and house dust ingestion for all scenarios and locations within the site, with the greatest estimated chronic intake in Smelterville during the historical scenario at

Table 5.14 (from Protocol document)
Summary of Baseline and Incremental Chronic
Daily Intakes (mg/kg/day)
(All Values are 10^{-6})

Scenario	Location	Contaminant	Baseline	Local Fish	Local Garden Vegetables	Drinking Groundwater	Extreme Soil/Dust Ingestion	Other Soil/Dust	Total All Intakes
Historical	Smelterville	Arsenic	827	--	--	446	22.3	34	1330
		Cadmium	522	56.7	553	8830	294	24.6	10300
		Lead	8300	284	1790	5990	28200	3170	47700
		Zinc	85900	--	8390	349000	17500	863	480000
		Antimony	292	--	--	--	658	39	989
		Mercury	69.8	--	--	-0	68.1	7.88	146
		Copper	363	--	--	--	624	31.1	1020
	Kellogg/ Wardner/ Page	Arsenic	817	--	--	126	63.4	21.8	1030
		Cadmium	493	56.7	553	1330	179	9.8	2620
		Lead	7180	284	1790	2590	18700	1980	32500
		Zinc	85000	--	8390	219000	12200	668	325000
		Antimony	272	--	--	--	508	18.4	798
		Mercury	62.9	--	--	-0	24.8	2.46	90.2
		Copper	346	--	--	--	573	24	943
	Pinehurst	Arsenic	774	--	--	--	42.4	20.7	837
		Cadmium	479	56.7	238	--	91.9	4.09	870
		Lead	4060	284	985	--	6340	352	12000
		Zinc	84700	--	6780	--	8720	321	101000
		Antimony	347	--	--	--	371	24.7	743
		Mercury	60.8	--	--	--	12.8	0.579	74.2
		Copper	--	--	--	--	--	--	--
Current	Smelterville	Arsenic	694	--	--	446	147	20.6	1310
		Cadmium	370	56.7	553	8830	205	16.1	10000
		Lead	5300	284	1790	5990	13000	1820	28200
		Zinc	84400	--	8390	349000	8180	362	450000
		Antimony	147	--	--	--	243	10.1	393
		Mercury	69.7	--	--	-0	52.5	3.40	126
		Copper	379	--	--	--	624	31.1	1040
	Kellogg/ Wardner/ Page	Arsenic	686	--	553	126	120	15.9	948
		Cadmium	348	56.7	1790	1330	126	7.52	2420
		Lead	4690	284	8390	2590	9260	1130	19700
		Zinc	84200	--	--	219000	7490	289	319000
		Antimony	150	--	--	--	210	610	366
		Mercury	64.6	--	--	-0	21.2	148	87.3
		Copper	365	--		--	573	24	962
	Pinehurst	Arsenic	641	--	--	--	42.4	20.7	704
		Cadmium	349	56.7	238	--	85	4.2	733
		Lead	3090	284	985	--	3940	252	8550
		Zinc	84000	--	6780	--	5070	168	96000
		Antimony	281	--	--	--	371	24.7	677
		Mercury	65.3	--	--	--	12.8	0.579	78.7
		Copper	--	--	--	--	--	--	--

Note: "--" indicates no data available.

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approximately 70% greater intake than for off-site background. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15. The additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the total baseline estimate. The sum of all incremental and baseline intakes for cadmium can yield an increased intake above background of 140% to 3,300% for current Pinehurst and historical Smelterville, respectively. The largest chronic intake increments are associated with primarily groundwater consumption and an order of magnitude less additional contribution from local garden vegetable consumption and extreme soil ingestion (due to "pica-type" behavior).

For **lead**, the bulk of the baseline chronic exposures/intakes is associated with house dust ingestion and less so, but equally between, residential yard soils and market basket food consumption in Smelterville and Kellogg/Wardner/Page. Residential yard soil contributions to total baseline lead intakes in Pinehurst due to direct exposure and ingestion, for both current and historical scenarios, are approximately 5% of the total estimated oral chronic intake. However, as discussed above and in Section 4.3.2 of the PD, house dust dependency on residential yard soil contaminant levels suggests that house dust contributions to intakes indirectly reflect soil contributions. The greatest estimated chronic lead intake is in Smelterville during the historical scenario at approximately 470% greater intake than for off-site background exposures. A comparison of chronic lead intakes in Table 5.12 shows that for the current scenario (since 1983) the ratios of community lead intakes to background intakes are approximately 3.6, 3.2, and 2.1, for Smelterville, Kellogg/Wardner/Page and Pinehurst, respectively. Additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for lead can yield an increased intake above background of 490% to 3,200% for current Pinehurst and historical Smelterville, respectively. The largest chronic intake increments are associated with primarily extreme soil ingestion (due to "pica-type" behavior), less with consumption of groundwater, and about equally

Table 5.15 (from Protocol document)
Summary of Incremental Chronic Daily Intake
Above Baseline (Percent)

Scenario	Location	Contaminant	Percent Incremental Oral Intake: Local Fish	Local Garden Vegetables	Drinking Groundwater	Extreme Soil/Dust Ingestion	Other Soil/ Dust	Total All Increments, %
Historical	Smelterville	Arsenic	--	--	54.9	2.7	4.1	61
		Cadmium	10.9	106	1692	56.3	4.7	1869
		Lead	3.4	21.6	72.2	340	38.2	480
		Zinc	--	9.8	406	20.4	1.0	437
		Antimony	--	--	--	225	13.4	238
		Mercury	--	--	0	97.6	11.3	109
		Copper	--	--	--	172	8.6	181
	Kellogg/ Wardner/ Page	Arsenic	--	--	15.4	7.8	2.7	26
		Cadmium	11.5	112	270	36.3	2.0	432
		Lead	4.0	24.9	36.1	260	27.6	353
		Zinc	--	9.9	257	14.3	0.8	282
		Antimony	--	--	--	187	6.8	194
		Mercury	--	--	0	39.4	3.9	43
		Copper	--	--	--	166	6.9	173
	Pinehurst	Arsenic	--	--	--	5.5	2.7	8
		Cadmium	11.8	49.7	--	19.2	0.9	82
		Lead	7.0	24.3	--	156	8.7	196
		Zinc	--	8.0	--	10.3	0.4	19
		Antimony	--	--	--	107	7.1	114
		Mercury	--	--	--	21.1	1.0	22
		Copper	--	--	--	--	--	--
Current	Smelterville	Arsenic	--	--	64.3	21.2	3.0	88
		Cadmium	15.3	149	2386	55.4	4.4	2611
		Lead	5.4	33.8	113	245	34.3	432
		Zinc	--	9.9	414	9.7	0.4	434
		Antimony	--	--	--	165	6.9	172
		Mercury	--	--	0	75.3	4.9	80
		Copper	--	--	--	165	8.2	173
	Kellogg/ Wardner/ Page	Arsenic	--	--	18.4	17.5	2.3	38
		Cadmium	16.3	159	382	36.2	2.2	596
		Lead	6.1	38.2	55.2	197	24.1	321
		Zinc	--	10.0	260	8.9	0.3	279
		Antimony	--	--	--	140	4.1	144
		Mercury	--	--	0	32.8	2.3	35
		Copper	--	--	--	157	6.6	164
	Pinehurst	Arsenic	--	--	--	6.6	3.2	10
		Cadmium	16.2	68.2	--	24.4	1.2	110
		Lead	9.2	31.9	--	128	8.2	177
		Zinc	--	8.1	--	6.0	0.2	14
		Antimony	--	--	--	132	8.8	141
		Mercury	--	--	--	19.6	0.9	21
		Copper	--	--	--	--	--	--

Note: "--" indicates no data available.

between local garden vegetable consumption and other soil/dust ingestion (at Pb concentrations representing the 95 percentile for residential yard soils).

Baseline **zinc** exposures/intakes are predominantly (≥ 95%) from drinking water for all scenarios and locations, including background. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15. The additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for zinc can yield an increased intake above background of 18% to 490% for current Pinehurst and historical Smelterville, respectively. The largest chronic intake increments are associated with groundwater consumption.

For **antimony**, the bulk of the baseline chronic exposures/intakes at the site is associated about equally with ingestion of house dust and consumption of market basket food. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15. The additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for antimony can yield an increased intake above background of approximately 360% to 1,170% for current Kellogg/Wardner/Page and historical Smelterville, respectively. The largest estimated chronic intake increments for antimony are associated with extreme soil/dust ingestion (due to "pica-type" behavior) for all areas and scenarios.

Baseline **mercury** exposures/intakes are primarily from market basket food for all scenarios and areas, including background. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15. The additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for mercury can yield an increased intake above background of approximately 25% to 146% for historical Pinehurst and historical

Smelterville, respectively. The largest estimated chronic intake increments for mercury are associated with extreme soil/dust ingestion (due to "pica-type" behavior) for all areas and scenarios.

For **copper**, the bulk of the baseline chronic exposures/intakes is associated with house dust ingestion, with the greatest estimated chronic copper intake in Kellogg/Wardner/Page during the current scenario at approximately 370% greater intake than for off-site background exposures. Additional exposures resulting from potentially high risk activities are evaluated as incremental intakes in Tables 5.14 and 5.15. The additional exposures/intakes in Table 5.14 are presented so that the intakes are directly additive in any combination to the baseline estimate. The sum of all incremental and baseline intakes for copper can yield an increased intake above background of approximately 1,100% for all scenarios and areas. The largest estimated chronic intake increments for copper are associated with extreme soil/dust ingestion (due to "pica-type" behavior) for all areas and scenarios.

It should be noted that intake estimates for groundwater consumption may be considered low for all metals since concentrations were measured as dissolved and not total or total recoverable. As noted in Section 3.3, comparison of limited analyses suggests that estimates for cadmium may be representative of total metal intake. Intake estimates for arsenic, lead, and zinc, however, are probably low, since the metal associated with the suspended solid fraction was observed to be a significant portion of the total metals measured in recent analyses of site groundwater (Pintlar, 1990).

5.4 Sub-chronic Exposures

Sub-chronic and short-term exposures under some conditions can result in extreme intakes of contaminant metals. Ingestion of extreme amounts of soil and dust during childhood (ages 2-6 years) has been referred to in the past as "pica-type" behavior and can result in extreme intakes of contaminants. The effects of this behavior on lifetime (chronic) intakes is presented above. The mean daily metal intakes from soils and dusts during the period at which this behavior is exhibited are quite high and are presented in Table 5.10. Soil and dust ingestion rates and consequent intakes associated with "pica-type" behavior can yield up to ten times greater metal intakes than that exhibited by the typical child during ages 2-6 years. In Smelterville, a childhood intake of up to 3.5 mg Pb/day is estimated for 1983 and 2.0 mg Pb/day for 1988. Extreme soil and dust ingestion rates in Kellogg/Wardner/Page can yield lead intakes of approximately 2.5 mg/day and 1.7 mg/day during 1983 and 1988, respectively. While "pica-type" behavior by children on the site was reported during the 1970s, it has not been associated with excess absorption in recent health studies at this site.

Consumption of local garden vegetable produce can yield extreme intakes for metals. Table 5.8 shows that up to 220 times as much lead can be ingested due to consumption of local garden vegetables grown in Smelterville/Kellogg versus that associated with the consumption of national market basket variety produce. Up to 62 times as much cadmium and 13 times as much zinc can be consumed in local garden produce versus market basket variety produce. The raising and consumption of local garden produce has been discouraged in the area for some time due to potentially extreme intakes of heavy metals.

Increased metal intakes can occur during exposures to extreme air concentrations measured during windy days in the Populated Areas. Tables A3.3 and A5.7 in Appendix A show that episodic events measured as maximum 24-hour metals concentrations in air during 8-hour high wind periods can be 4 to 90 times greater than annual mean levels in the case of lead during 1987. Twenty-four-hour average TSP air concentrations (measured as PM_{10}) during the summer and fall of 1987 and 1989 at any of the monitoring stations show statistically significant correlations ($r \geq 0.7$ and $p \leq 0.01$) with same day 8-hour TSP measurements (as high-vol total particulates during high wind periods) at various and multiple stations throughout the site. Exposures and consequent intakes resulting from inhalation during episodic events are estimated for lead and presented in Table 7.10 of the PD. For the 2-year-old child in Smelterville, the lead intake associated with inhalation of extreme air lead levels (1-2 μg Pb/m³) could yield an incremental increase in blood lead level of approximately 1-2 μg/dl.

Deposition of windblown dusts has significant impact on other receptor media in the area. Section 4 describes the impacts that windblown fugitive dusts have on receptor soils and dusts in the residential area. Total suspended particulate (TSP) measurements were greater than or equal to 150 μg/m³ 18% of the time from July through October 1987 (measurement period was from 12:00 p.m. to 8:00 p.m. for 118 consecutive days). The lead concentration in air particulates ranged from 200 to 41,000 μg/gm solids (see Table 4.3), similar to the range of lead concentrations reported for fugitive dust sources (found in Table 2.13 of the PD). Lead concentration in dry deposition solids have been reported to be similar to the lead concentration in suspended air particulate matter. The maintenance of residential soils at 5,000 μg/gm via deposition of windblown dusts could yield a childhood blood lead increase of approximately 20 μg/dl (5,000 μg/Pb/gm x 0.065 gm/day ingestion x 20% GI absorption x 0.30 day/dl response coefficient; see Section 8.2.2.3 of the PD). Direct contact of the same windblown dusts via inhalation during wind events yields a blood lead increase of 1-2 μg/dl, approximately 10 to 20 times less than that possible from lead intake associated with the ingestion of windblown and deposited solids. This analysis suggests that the primary concern with windblown dusts and lead in air is the accumulation of contaminated solids at population receptor points and less with direct contact via inhalation. Sub-chronic and chronic exposures to wind-transported solids as soils and dusts could conservatively yield 10-20 times the blood lead response via the ingestion route relative to the acute and sub-chronic exposures presented in air via the inhalation route. Sub-chronic exposures for children to lead contaminated media will be presented and evaluated separately in Section 6.2.2.

6.0 RISK CHARACTERIZATION

Risk characterization is accomplished by comparing exposure point concentrations and estimated intakes/doses to ARARs and other TBC guidances, including toxicological based endpoints and health advisories, for each of the site contaminants of concern. To characterize potential noncarcinogenic health effects, comparisons are made between estimated chronic intakes of contaminants and toxicity values (expressed as acceptable daily chronic intakes). To characterize potential carcinogenic effects or probabilities that an individual will develop cancer over a lifetime of exposure are estimated from projected intakes and chemical-specific dose-response information.

6.1 Carcinogenic Risk

Chemical-specific carcinogenic risk is estimated as:

$$\text{Cancer Risk}_i = CDI_i \times CPF_i$$

where: CDI_i = chronic daily intake for chemical i (mg/kg-day), and
CPF_i = cancer potency factor for chemical i $(\text{mg/kg-day})^{-1}$.

Estimation of cancer risk due to simultaneous exposures to several carcinogens assumes an additive relationship and no synergistic or antagonistic effects (USEPA, 1986b), and is expressed as:

$$\text{Cancer Risk}_{(total)} = \sum_i \text{Cancer Risk}_i$$

In a revision to the National Contingency Plan (USEPA, 1989b and 1990d), USEPA recommends that an acceptable carcinogenic risk to an exposed individual over a lifetime from a carcinogenic hazardous constituent in any medium is less than 1×10^{-6}. While 1×10^{-6} is described as the overall goal, site- or remedy-specific factors preventing the achievement of this goal, may require the consideration of allowing greater levels of risk. As risks increase above 1×10^{-6}, they become less desirable, and the risks to an individual should not exceed 1×10^{-4}.

Cancer Potency Factors (CPFs) for the site contaminants of concern are only available for arsenic via ingestion, and for arsenic and cadmium via the inhalation route of exposure.

Available CPFs for Site Contaminants of Concern[a]
$(mg/kg\text{-}day)^{-1}$

	Oral Exposure	Inhalation Exposure
Arsenic	1.5[b]	50[c]
Cadmium	-	6.1

(a) Source: USEPA, 1988b.
(b) Source: USEPA, 1989k.
(c) Inhalation slope factor is in terms of absorbed dose. Absorption/deposition of inhaled arsenic is estimated to be 30%.

The product of the route-specific CDIs for arsenic and cadmium from Tables 5.11 and 5.14 and the above CPFs are summarized in Table 6.1 as route-specific **baseline** carcinogenic risk estimates, and in Table 6.2 as total baseline and **incremental** carcinogenic risk estimates. Total risk associated with various potentially high risk activities are determined by adding any combination of the incremental risks for each scenario to the respective baseline estimate, yielding a total combined risk. Figure 6.1 graphically presents the cancer risk estimates found in Table 6.2 for total arsenic and cadmium intakes.

Table 6.1
Summary of Baseline Carcinogenic Risk Estimates[(a)]

Scenario	Location	Contaminant	Route-Specific Risk: Inhalation	Yard Soil Ingestion	House Dust Ingestion	Other Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral	Total, All Routes
Historical	Smelterville	Arsenic	1.4×10^{-4}	3.4×10^{-5}	4.6×10^{-5}	1.6×10^{-5}	8.1×10^{-5}	1.1×10^{-3}	1.2×10^{-3}	1.3×10^{-3}
		Cadmium	1.4×10^{-4}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	2.8×10^{-4}	3.4×10^{-5}	4.6×10^{-5}	1.6×10^{-5}	8.1×10^{-5}	1.1×10^{-3}	1.2×10^{-3}	1.3×10^{-3}
	Kellogg/ Wardner/Page	Arsenic	2.1×10^{-4}	2.0×10^{-5}	4.5×10^{-5}	8.2×10^{-6}	8.1×10^{-5}	1.1×10^{-3}	1.3×10^{-3}	1.5×10^{-3}
		Cadmium	1.1×10^{-4}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	3.2×10^{-4}	2.0×10^{-5}	4.5×10^{-5}	8.2×10^{-6}	8.1×10^{-5}	1.1×10^{-3}	1.2×10^{-3}	1.5×10^{-3}
	Pinehurst	Arsenic	5.0×10^{-5}	1.3×10^{-5}	7.2×10^{-6}	5.4×10^{-6}	8.1×10^{-5}	1.1×10^{-3}	1.2×10^{-3}	1.2×10^{-3}
		Cadmium	6.8×10^{-5}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	1.2×10^{-4}	1.3×10^{-5}	7.2×10^{-6}	5.4×10^{-6}	8.1×10^{-5}	1.1×10^{-3}	1.2×10^{-3}	1.2×10^{-3}
Current	Smelterville	Arsenic	7.8×10^{-5}	2.8×10^{-5}	5.7×10^{-5}	1.2×10^{-5}	8.1×10^{-5}	8.6×10^{-4}	1.0×10^{-3}	1.1×10^{-3}
		Cadmium	5.8×10^{-5}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	1.4×10^{-4}	2.8×10^{-5}	5.7×10^{-5}	1.2×10^{-5}	8.1×10^{-5}	8.6×10^{-4}	1.0×10^{-3}	1.1×10^{-3}
	Kellogg/ Wardner/Page	Arsenic	3.8×10^{-5}	2.2×10^{-5}	5.8×10^{-5}	9.5×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	1.0×10^{-3}	1.1×10^{-3}
		Cadmium	1.8×10^{-5}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	5.6×10^{-5}	2.2×10^{-5}	5.8×10^{-5}	9.5×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	1.0×10^{-3}	1.1×10^{-3}

Table 6.1 (Continued)
Summary of Baseline Carcinogenic Risk Estimates[(a)]

Scenario	Location	Contaminant	Route-Specific Risk: Inhalation	Yard Soil Ingestion	House Dust Ingestion	Other Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral	Total, All Routes
	Pinehurst	Arsenic	4.7×10^{-6}	1.3×10^{-5}	7.2×10^{-6}	5.4×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	9.6×10^{-4}	9.8×10^{-4}
		Cadmium	1.4×10^{-5}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	1.9×10^{-5}	1.3×10^{-5}	7.2×10^{-6}	5.4×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	9.6×10^{-4}	9.8×10^{-4}
Background	All	Arsenic	4.7×10^{-6}	5.1×10^{-6}	2.4×10^{-5}	2.2×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	9.6×10^{-4}	9.8×10^{-4}
		Cadmium	5.7×10^{-6}							
		Lead								
		Zinc								
		Antimony								
		Mercury								
		Copper								
		Total	1.0×10^{-5}	5.1×10^{-6}	2.4×10^{-5}	2.2×10^{-6}	8.1×10^{-5}	8.6×10^{-4}	9.6×10^{-4}	9.8×10^{-4}

(a) Contaminants and media for which risk is not estimated is due to lack of either an appropriate CPF and/or media concentrations from which intakes can be estimated. CPFs are available only for arsenic (oral and inhalation) and cadmium (inhalation only). Intake estimates are derived from Table 5.11.

Baseline total carcinogenic risk is predominantly due to exposures associated with consumption of market basket produce, with an approximately 30% increase above background (9.8×10^{-4}) due to site exposures. The greatest baseline cancer risk due to arsenic exposures is associated with the historical scenario in Smelterville, which is approximately 34% greater than the estimated offsite background risk. The background risk (9.8×10^{-4}) is considered excessive, and the increase associated with site exposures may not be significant. A significant portion of arsenic intakes from market basket produce is associated with seafood consumption; the species of arsenic in seafood is typically a form that is rapidly absorbed and excreted but does not appear to pose the same amount of risk as inorganic arsenic. Consequently, health risk due to arsenic intakes from market basket food consumption may be overestimated. However, a doubling of background cancer risk could result from the chronic consumption of contaminated groundwater during the historical scenario in Smelterville and Kellogg [$(1.4 + 0.67) \times 10^{-3}/(0.97 \times 10^{-3}) = 2.1$, for Smelterville; and $(1.5 + 0.19) \times 10^{-3}/(0.97 \times 10^{-3}) = 1.7$, for Kellogg]. The confidence level associated with the arsenic <u>oral</u> CPF is low-to-moderate (USEPA, 1988e and 1989k); therefore, the uncertainty associated with the estimated carcinogenic risk due to oral arsenic exposures could result in overestimates of the actual risks due to arsenic ingestion.

Carcinogenic risk associated with the <u>inhalation</u> route of exposure only is graphically presented in Figure 6.2, with about equal contributions of risk from arsenic and cadmium. A relatively high degree of confidence is associated with these estimates of risk to lung cancer. Air concentrations are believed to be representative; the CPFs for both arsenic and cadmium are derived from human studies suggesting that a high degree of confidence could be associated with the risk estimates. Approximately 28 times greater risk (2.8×10^{-4}) to lung cancer is associated with the historical scenario for Smelterville relative to background (1.0×10^{-5}), and about 14 times greater risk for current Smelterville compared to background due to the inhalation route of exposure.

Figure 6.2
Total Baseline Lung Carcinogenic Risk Due to As and Cd Inhalation

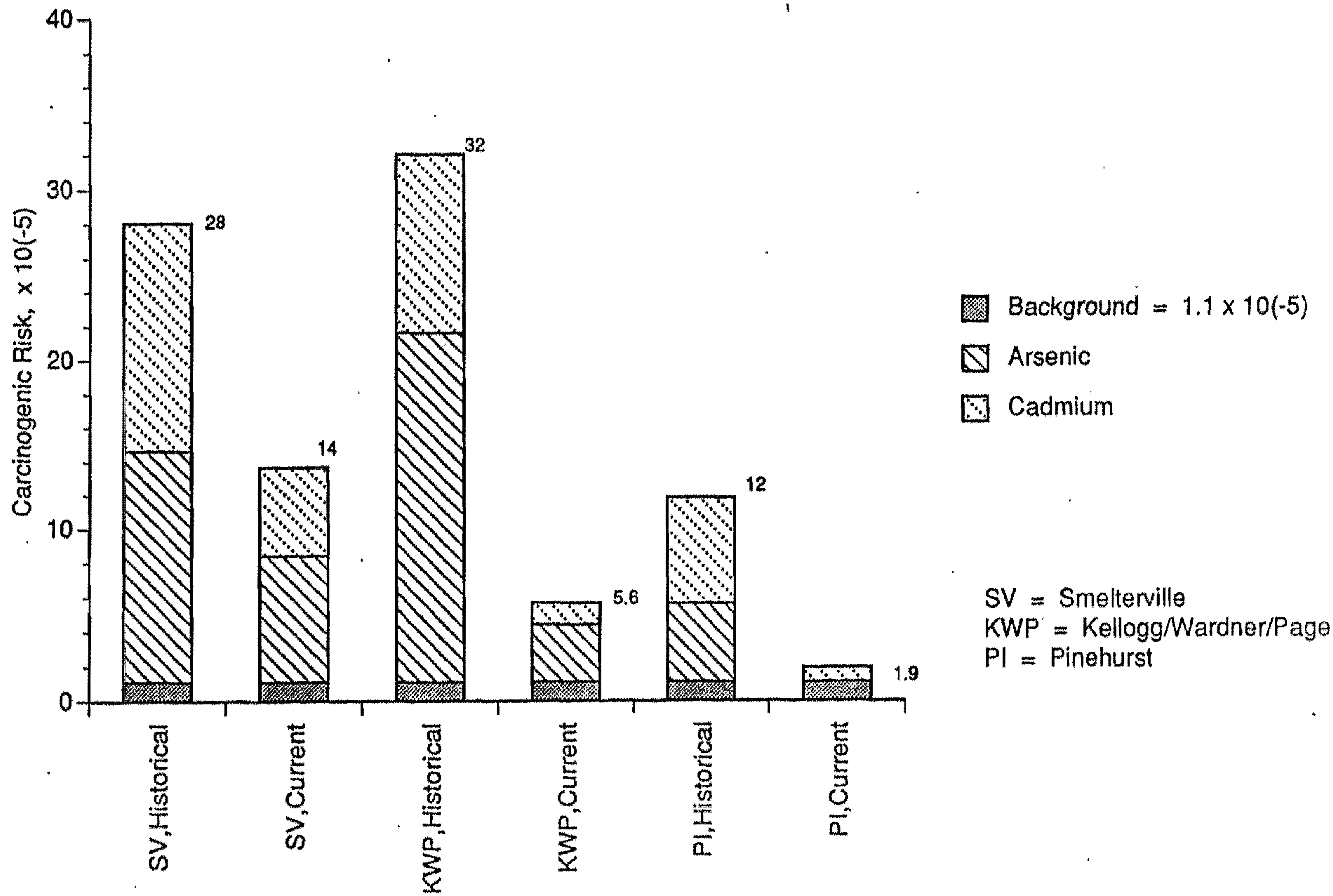

Table 6.2
Summary of Baseline and Incremental Carcinogenic Risk Estimates[a]

Scenario	Location	Contaminant	Baseline	Local Fish	Local Garden Vegetables	Drinking/ Groundwater	Extreme Soil/Dust Ingestion	Other Soil/Dust	Total, All Intakes
Historical	Smelterville	Arsenic	$1.3x10^{-3}$			$6.7x10^{-4}$	$3.3x10^{-5}$	$5.1x10^{-5}$	$2.1x10^{-3}$
		Cadmium	$1.4x10^{-4}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$1.4x10^{-3}$			$6.7x10^{-4}$	$3.3x10^{-5}$	$5.1x10^{-5}$	$2.1x10^{-3}$
	Kellogg/ Wardner/Page	Arsenic	$1.5x10^{-3}$			$1.9x10^{-4}$	$9.5x10^{-5}$	$3.3x10^{-5}$	$1.8x10^{-3}$
		Cadmium	$1.1x10^{-4}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$1.6x10^{-3}$			$1.9x10^{-4}$	$9.5x10^{-5}$	$3.3x10^{-5}$	$1.8x10^{-3}$
	Pinehurst	Arsenic	$1.2x10^{-3}$				$6.4x10^{-5}$	$3.1x10^{-5}$	$1.3x10^{-3}$
		Cadmium	$6.8x10^{-5}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$1.3x10^{-3}$				$6.4x10^{-5}$	$3.1x10^{-5}$	$1.3x10^{-3}$
Current	Smelterville	Arsenic	$1.1x10^{-3}$			$6.7x10^{-4}$	$2.2x10^{-4}$	$3.1x10^{-5}$	$2.0x10^{-3}$
		Cadmium	$5.8x10^{-5}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$1.2x10^{-3}$			$6.7x10^{-4}$	$2.2x10^{-4}$	$3.1x10^{-5}$	$2.0x10^{-3}$
	Kellogg/ Wardner/Page	Arsenic	$1.1x10^{-3}$			$1.9x10^{-4}$	$1.8x10^{-4}$	$2.4x10^{-5}$	$1.5x10^{-3}$
		Cadmium	$1.8x10^{-5}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$1.1x10^{-3}$			$1.9x10^{-4}$	$1.8x10^{-4}$	$2.4x10^{-5}$	$1.5x10^{-3}$
	Pinehurst	Arsenic	$9.8x10^{-4}$				$6.4x10^{-5}$	$3.1x10^{-5}$	$1.1x10^{-3}$
		Cadmium	$1.4x10^{-5}$						
		Lead							
		Zinc							
		Antimony							
		Mercury							
		Copper							
		Total	$9.8x10^{-4}$				$6.4x10^{-5}$	$3.1x10^{-5}$	$1.1x10^{-3}$

(a) Contaminants and media for which risk is not estimated is due to lack of either an appropriate CPF and/or media concentrations from which intakes can be estimated. CPFs are available only for arsenic (oral and inhalation) and cadmium (inhalation only). Intake estimates are derived from Table 5.14.

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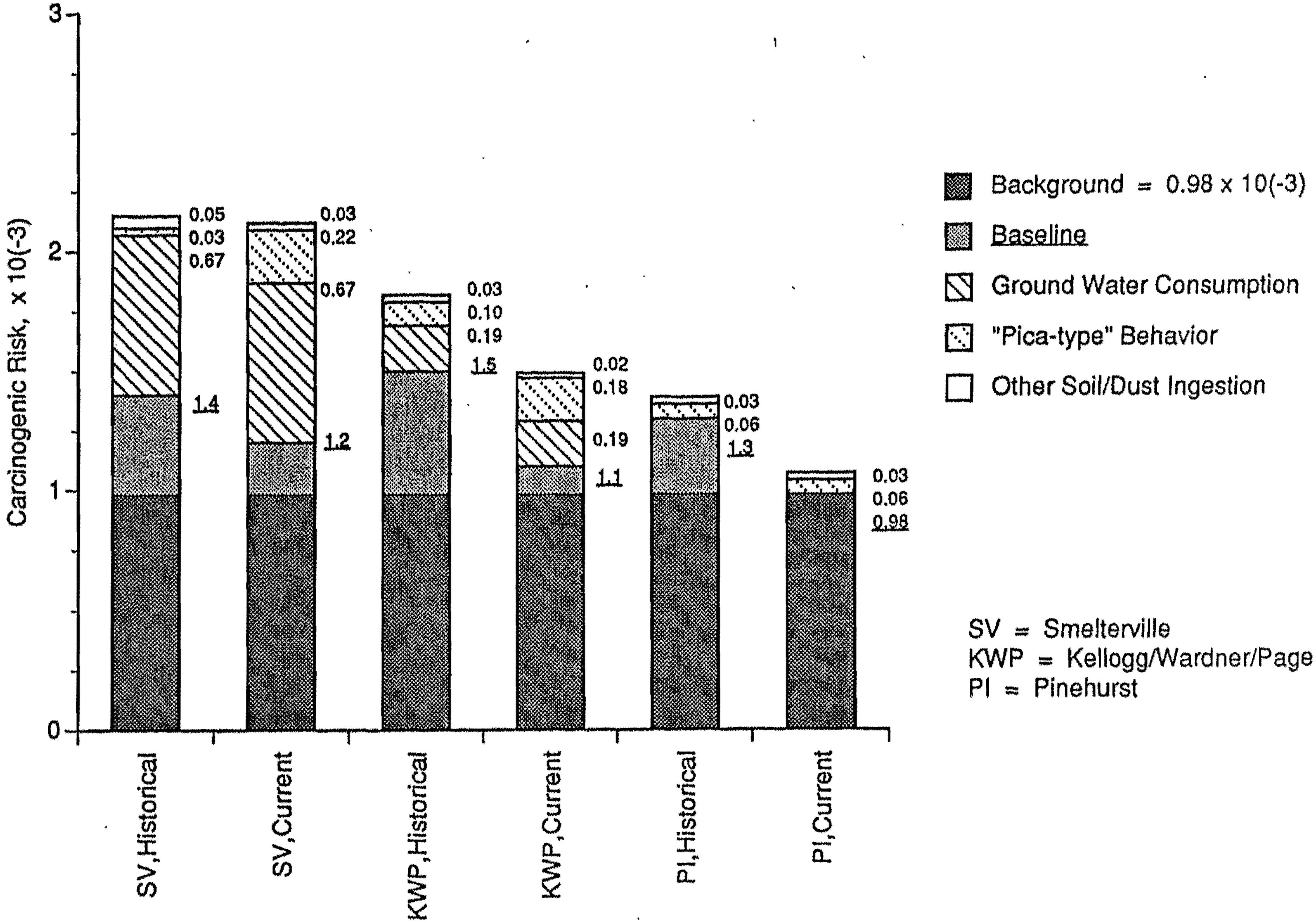
Figure 6.1
Total Carcinogenic Risk Due To As and Cd Intakes



Total carcinogenic risk at the site could be greater than estimated due to multiple and simultaneous exposures to chemicals for which information regarding cancer dose-response and/or synergistic relationships are not available. While cancer potency for lead has not been estimated, the USEPA has established a "low potency" classification for this chemical (USEPA, 1989f) which suggests excessive lead exposures could contribute to carcinogenic risk. Greater metal intakes are associated with the population residing on site prior to the period evaluated (pre-1971), and the risks reported here are those associated with exposures in the home environment (for the homemaker) and not the occupational environment.

The community at large, including workers, exhibits increased cancer mortality rates relative to the region. Table 6.3 summarizes tumor registry data for the period 1977 to 1986 for Shoshone County and the State of Idaho for comparison. Also presented are observed versus expected cases determined by a method approved and nationally applied by the National Cancer Institute (IDHW, 1990b). In general, incidence of cancer is greater than expected, and greater in Shoshone County than in the State of Idaho with relative percent increases about the same for both sexes. The most significant increases are associated with respiratory cancers for both males and females of Shoshone County, with male incidences greater than female. Approximately 90% of the respiratory cases are due to cancer of the lung and bronchus. This may be related to the increased lung cancer risk estimates due to inhalation of arsenic and cadmium presented above for site residents.

Other smelter related contaminant emissions could also contribute to the observed excess cancer mortalities. The National Cancer Institute has reported excess mortality from lung cancer, independent of smoking habits, in Shoshone County as well as in other smelting counties in the United States where smelters are located. This increase was found in females as well as males, a finding which suggests that the carcinogenic hazard of the smelter extends beyond the smelter work force to the general community (Blot and Fraumeni, 1975). True mortality rates due to area exposures are expected to be

Table 6.3

Shoshone County Population Cancer Rates For 1977-1986[a]

AVERAGE AGE-ADJUSTED CANCER RATES

Physiologic Site	Males: Idaho State	Males: Shoshone County	Females: Idaho State	Females: Shoshone County
All sites	340.9	416.1	272.7	288.9
Respiratory	**68.1**	**152.4**	**23.8**	**38.5**
Digestive	68.4	75.3	50.2	60.9
Urinary	34.6	37.6	10.3	16.7

OBSERVED AND EXPECTED CANCER CASES FOR SHOSHONE COUNTY

Physiologic Sites	Males: Expected	Males: Observed	Females: Expected	Females: Observed
All sites	352.7	380	306.3	297
Respiratory	**84.3**	**137**	**24.6**	41
Digestive	89.0	73	68.5	61
Urinary	33.5	34	12.3	17

(a) Source: IDHW, 1990b.

greater than demonstrated by registry data since some of the exposed population have moved out of the area and been replaced by non- or less-exposed individuals.

6.2 Noncarcinogenic Risk

Noncarcinogenic risks are evaluated by comparison of contaminant-specific chronic daily intakes (CDIs) for each of the pertinent exposure routes (from Tables 5.11 and 5.14) to the appropriate reference doses (RfDs) for antimony, arsenic, cadmium, copper, mercury and zinc. Due to the unavailability of an appropriate RfD and the sensitivity of children to lead, exposures are evaluated by blood lead surveys conducted on site and a dose-response analysis for children using an integrated uptake/biokinetic dose-response model developed by the USEPA Environmental Criteria and Assessment Office (ECAO) (USEPA, 1988d).

6.2.1 Chronic Exposures and Associated Health Risks

The risk of adverse noncarcinogenic health effects from contaminant exposures is expressed in terms of the Hazard Index (HI). The HI is the ratio of the estimated human intake to the acceptable intake, or the estimated intake believed to be safe. The chemical-specific HI_i is calculated for chronic exposures as:

$$HI_i = CDI_i/AIC_i$$

where:

HI_i = chemical-specific Hazard Index for chronic exposures (unitless),

CDI_i = chemical-specific Chronic Daily Intake (mg/kg-day), and

AIC_i = $RfD_{(chronic)}$ = Acceptable Intake for Chronic exposures (mg/kg-day).

The cumulative or total HI for specific toxic effects and target organs is estimated by summing the individual contaminant HIs for those contaminants with common adverse effects. Excess risk is determined to be where $HI_{(specific\ disease)} \geq 1.0$ and when $HI_{(specific\ disease)}$ is different from that associated with background exposures.

The noncarcinogenic health effects and associated AICs for the site contaminants of concern are as follows:

Noncarcinogenic Effects and Associated RfDs for Site Contaminants of Concern

Chemical	Exposure Route	Pathology	AIC,mg/kg-day[(a)]
Antimony[(d)]	Oral	GI Irritation	4×10^{-4}
Arsenic[(f)]	Oral	Skin Lesions	1×10^{-3}
Cadmium[(e)]	Oral	Renal Dysfunction	
		food	1×10^{-3}
		water	5×10^{-4}
Copper[(e)]	Oral	GI Irritation	1.3 mg/L[(b)]
Lead[(g)]	Inhalation & Oral	Various, including Renal Dysfunction, Anemia & Neurobehavioral Deficiencies	Unavailable
Mercury[(e,h)]	Oral	Renal Dysfunction	3×10^{-4} [(c)]
Zinc[(e)]	Oral	Anemia	0.20

Chemicals with common effects include:

Cadmium, lead and mercury for renal toxicity.
Lead and zinc for anemia.
Antimony and copper for production of gastrointestinal (GI) irritation.

(a) USEPA, 1988b
(b) USEPA, 1984e
(c) USEPA, 1989k
(d) USEPA, 1989h
(e) USEPA, 1984c,d,f,and g
(f) ATSDR, 1987
(g) JEG et al., 1989
(h) USEPA, 1987

The oral RfD (in this case AIC) for copper is derived from the drinking water standard; and assuming the standard represents a total acceptable intake, a 2-liter/day water consumption rate, and an average lifetime body weight of 70 kg, an estimated AIC or $RfD_{(chronic)}$ of 3.7×10^{-2} mg/kg-day is derived for copper. The Minimal Risk Level (MRL) of 1×10^{-3} mg/kg-day proposed by ATSDR (ATSDR, 1987) is used for the oral $RfD_{(chronic)}$ or AIC for arsenic. Subtotal oral HIs for cadmium and mercury are summed to yield a total HI characterizing risk to renal disease [$HI_{(renal\ disease)} = HI_{Cd} + HI_{Hg}$], and antimony and copper subtotal oral HIs are summed for characterizing total risk to gastrointestinal (GI) toxicity [$HI_{(GI\ toxicity)} = HI_{Sb} + HI_{Cu}$].

Chemical-specific noncarcinogenic risk estimates, in terms of HIs, are calculated by dividing intake estimates from Tables 5.11 and 5.14 by the appropriate AICs (above). Chemical and route-specific HIs are presented in Table 6.4 for baseline risk and Table 6.5 for incremental risk due to potentially high exposure activities. Note that there are no inhalation-specific AICs for determination of noncarcinogenic effects associated with the inhalation route of exposure for any of the site contaminants of concern. Figures 6.3, 6.4, 6.5 and 6.6a and b graphically summarize the baseline and incremental risks (in terms of total/cumulative oral HIs) for occurrence of skin lesions (HI_{As}), hematopoietic effects (HI_{Zn}), gastrointestinal toxicity ($HI_{Sb} + HI_{Cu}$) and renal dysfunction ($HI_{Cd} + HI_{Hg}$), respectively.

Risk for **skin lesions** due to **arsenic** exposures via the oral route, presented in Figure 6.3, is greatest in Smelterville for the historical baseline scenario (HI = 0.82), and an incremental risk is greatest due to groundwater consumption (HI = 0.45), yielding a total HI of approximately 1.3. Greatest arsenic contributions to baseline exposures and intakes is due to National market basket food consumption (80-90% of baseline intakes), with minor contributions from other exposures. The historical baseline arsenic exposures for Smelterville, as a worst case, are approximately 26% greater than that for northern rural Idaho background. The other potential incremental exposure/intake routes for

Table 6.4
Summary of Baseline Noncarcinogenic Risk Estimates[a]
(Chronic Hazard Indices)

			Route-Specific Hazard Index						
Scenario	Location	Contaminant	Inhalation	Yard Soil Ingestion	House Dust Ingestion	Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral
Historical	Smelterville	Arsenic		0.022	0.031	0.010	0.054	0.70	0.82
		Cadmium		0.013	0.058	0.0059	0.14	0.35	0.57
		Lead							
		Zinc		0.0022	0.018	0.0011	0.41	0.0015	0.43
		Antimony		0.053	0.27	0.030		0.35	0.70
		Mercury		0.010	0.026	0.0054	0.024	0.17	0.24
		Copper		0.00080	0.0077	0.00034			0.0088
		Total		0.10	0.40	0.052	0.62	1.6	2.8
	Kellogg/ Wardner/Page	Arsenic		0.0014	0.030	0.0055	0.054	0.70	0.80
		Cadmium		0.0067	0.042	0.0031	0.14	0.35	0.54
		Lead							
		Zinc		0.0016	0.015	0.00076	0.41	0.0015	0.43
		Antimony		0.018	0.29	0.0093		0.35	0.67
		Mercury		0.0040	0.013	0.0018	0.024	0.17	0.21
		Copper		0.00065	0.0072	0.00028			0.0081
		Total		0.044	0.39	0.020	0.62	1.6	2.7
	Pinehurst	Arsenic		0.0085	0.0048	0.0036	0.054	0.70	0.77
		Cadmium		0.0031	0.042	0.0013	0.14	0.35	0.54
		Lead							
		Zinc		0.00095	0.016	0.00043	0.41	0.0015	0.43
		Antimony		0.018	0.48	0.0076		0.35	0.86
		Mercury		0.0011	0.010	0.00048	0.024	0.17	0.21
		Copper							
		Total		0.032	0.55	0.013	0.62	1.6	2.8
Current	Smelterville	Arsenic		0.019	0.038	0.0080	0.054	0.57	0.69
		Cadmium		0.012	0.042	0.0050	0.14	0.35	0.55
		Lead							
		Zinc		0.0014	0.014	0.00059	0.41	0.0015	0.43
		Antimony		0.020	0.14	0.0080		0.19	0.36
		Mercury		0.0060	0.027	0.0025	0.024	0.17	0.23
		Copper		0.00080	0.0077	0.00034		0.00051	0.0093
		Total		0.058	0.26	0.024	0.62	1.3	2.3
	Kellogg/ Wardner/Page	Arsenic		0.015	0.039	0.0064	0.054	0.57	0.68
		Cadmium		0.0066	0.034	0.0028	0.14	0.35	0.54
		Lead							
		Zinc		0.0013	0.013	0.00054	0.41	0.0015	0.43
		Antimony		0.010	0.16	0.0042		0.19	0.36
		Mercury		0.0036	0.013	0.0015	0.024	0.17	0.21
		Copper		0.00065	0.0072	0.00028		0.00051	0.0086
		Total		0.037	0.26	0.015	0.62	1.3	2.2

Table 6.4 (Continued)
Summary of Baseline Noncarcinogenic Risk Estimates[(a)]
(Chronic Hazard Indices)

			Route-Specific Hazard Index						
Scenario	Location	Contaminant	Inhalation	Yard Soil Ingestion	House Dust Ingestion	Soil/Dust Ingestion	Drinking Water	Market Basket Food	Total Oral
	Pinehurst	Arsenic		0.0085	0.0048	0.0036	0.054	0.57	0.64
		Cadmium		0.0034	0.040	0.0015	0.14	0.35	0.53
		Lead							
		Zinc		0.00070	0.013	0.00030	0.41	0.0015	0.43
		Antimony		0.018	0.48	0.0076		0.19	0.70
		Mercury		0.0011	0.019	0.00048	0.024	0.17	0.21
		Copper							
		Total		0.032	0.55	0.014	0.62	1.3	2.5
Background	All	Arsenic		0.0034	0.016	0.0015	0.054	0.57	0.65
		Cadmium		0.00027	0.0013	0.00012	0.14	0.35	0.49
		Lead							
		Zinc		0.00016	0.00077	0.000069	0.41	0.0015	0.41
		Antimony		0.00094	0.0044	0.00040		0.19	0.19
		Mercury		0.00011	0.00054	0.000048	0.024	0.17	0.19
		Copper		0.00026	0.0012	0.00011		0.00051	0.0021
		Total		0.0052	0.024	0.0023	0.62	1.3	2.0

(a) Contaminants and media for which the hazard index is not estimated is due to lack of either an appropriate reference dose (RfD), in terms of an acceptable chronic daily intake (AIC), and/or media concentrations from which intakes can be estimated. RfDs are available for antimony, cadmium, mercury and zinc; oral route only. Intake estimates are derived from Table 5.11.

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Table 6.5
Summary of Baseline and Incremental Noncarcinogenic Risk Estimates[a] (Chronic Hazard Indices)

Scenario	Location	Contaminant	Baseline	Local Fish	Local Garden Vegetables	Drinking/ Ground Water	Extreme Soil/Dust Ingestion	Other Soil/Dust	Total, All Intakes
Historical	Smelterville	Arsenic	0.82			0.45	0.022	0.034	1.3
		Cadmium	0.57	0.057	0.55	0.18	0.29	0.025	0.19
		Lead							
		Zinc	0.43		0.042	1.7	0.088	0.0043	2.3
		Antimony	0.70				1.6	0.098	2.4
		Mercury	0.24			~0	0.23	0.026	0.50
		Copper	0.0088				0.017	0.00084	0.027
		Total	2.8	0.057	0.59	.20	2.2	0.18	26
	Kellogg/ Wardner/Page	Arsenic	0.80			0.13	0.063	0.022	1.0
		Cadmium	0.54	0.057	0.55	2.7	0.18	0.0098	4.0
		Lead							
		Zinc	0.43		0.042	1.1	0.061	0.0033	1.6
		Antimony	0.67				1.3	0.046	2.0
		Mercury	0.21			~0	0.083	0.0082	0.30
		Copper	0.0081				0.015	0.00065	0.024
		Total	2.7	0.057	0.59	3.9	1.6	0.089	9
	Pinehurst	Arsenic	0.77				0.042	0.021	0.83
		Cadmium	0.54	0.057	0.24		0.092	0.0041	0.93
		Lead							
		Zinc	0.43		0.034		0.044	0.0016	0.51
		Antimony	0.86				0.93	0.062	1.9
		Mercury	0.21				0.043	0.0019	0.25
		Copper							
		Total	2.8	0.057	0.27		1.1	0.088	4.4
Current	Smelterville	Arsenic	0.69			0.45	0.15	0.021	1.3
		Cadmium	0.55	0.057	0.55	0.18	0.21	0.016	0.19
		Lead							
		Zinc	0.43		0.042	1.7	0.041	0.0018	2.2
		Antimony	0.36				0.61	0.025	1.0
		Mercury	0.23			~0	0.18	0.011	0.42
		Copper	0.0093				0.017	0.00084	0.027
		Total	2.3	0.057	0.59	20	1.2	0.075	24
	Kellogg/ Wardner/Page	Arsenic	0.68			0.13	0.12	0.016	0.95
		Cadmium	0.54	0.057	0.55	2.7	0.13	0.0075	4.0
		Lead							
		Zinc	0.43		0.042	1.1	0.037	0.0014	1.6
		Antimony	0.36				0.053	0.015	0.91
		Mercury	0.21			~0	0.071	0.0049	0.29
		Copper	0.0086				0.015	0.00065	0.024
		Total	2.2	0.057	0.59	3.9	0.89	0.045	7.8

Table 6.5 (Continued)
Summary of Baseline and Incremental Noncarcinogenic Risk Estimates[a] (Chronic Hazard Indices)

Scenario	Location	Contaminant	Baseline	Local Fish	Local Garden Vegetables	Drinking/ Ground Water	Extreme Soil/Dust Ingestion	Other Soil/Dust	Total, All Intakes
	Pinehurst	Arsenic	0.64				0.042	0.021	0.70
		Cadmium	0.53	0.057	0.24		0.085	0.0042	0.92
		Lead							
		Zinc	0.43		0.034		0.025	0.00084	0.49
		Antimony	0.70				0.93	0.062	1.7
		Mercury	0.21				0.043	0.0019	0.25
		Copper							
		Total	2.5	0.057	0.27		1.1	0.90	4.1

(a) Contaminants and media for which the hazard index is not estimated is due to lack of either an appropriate reference dose (RfD), in terms of an acceptable chronic daily intake (AIC), and/or media concentrations from which intakes can be estimated. RfDs are available for antimony, cadmium, mercury and zinc; oral route only. Intake estimates are derived from Table 5.14.

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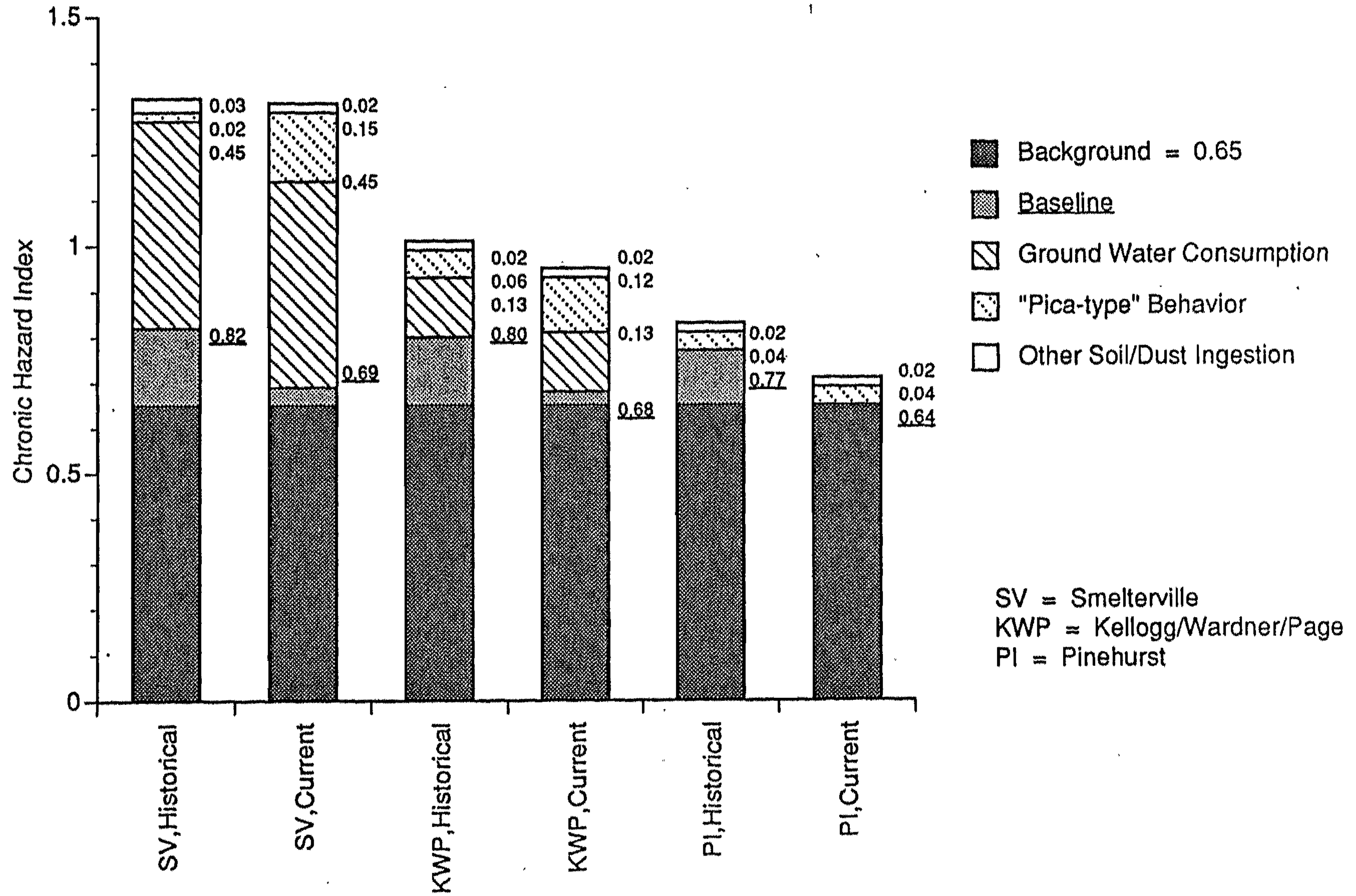
Figure 6.3
Noncarcinogenic Risk For Skin Lesions
(Risks associated with As intakes)



arsenic appear to pose little additional risk to noncarcinogenic adverse health effects relative to background.

Evaluation of baseline **zinc** exposures and oral intakes indicates that for all scenarios and populations of concern, current drinking water can account for 95% to approximately 100% of baseline intakes. The most sensitive and potentially toxic effects of zinc exposures are manifested as **anemia**, with baseline risks for all target and background populations being about equal (HI $\simeq$ 0.4) due to exposures from current drinking water sources. Figure 6.4 presents the estimated HIs for anemia due to zinc exposures for target and background populations. Excess risk to anemia could result from baseline exposures plus groundwater consumption in Smelterville ($HI_{(anemia)}$ = 2.1) and Kellogg/ Wardner/Page ($HI_{(anemia)}$ = 1.5) for both current and historical scenarios. Risk to anemia resulting from baseline and incremental exposures is estimated as lower limits since risk is not characterized for concomitant and excess lead exposures. Estimates of adverse health risk associated with zinc from consumption of groundwater are low relative to the potential risk since groundwater concentrations used for intake estimates are based on dissolved metals and not total or total recoverable. A relatively high level of certainty is associated with the oral risk estimates as lower limits since a high degree of confidence is associated with both intake estimates (as lower limits for groundwater) and the oral RfD for zinc.

Antimony and **copper** exposures and consequent intakes via the oral route can result in **gastrointestinal toxicity**. Baseline risk to gastrointestinal effects in terms of $HI_{(Sb + Cu)}$ are less than 1.0 for all scenarios and target populations. Figure 6.5 presents the estimated HIs for gastrointestinal toxicity due to antimony and copper intakes, with antimony contributing > 95% of the toxicity. "Pica-type" behavior could result in unacceptable lifetime and sub-chronic risk to gastrointestinal toxicity ($HI_{(Sb + Cu)} \geq 1.0$) from extreme ingestion of soil and dust during the historical scenario for all populations of concern. Current house dust antimony concentrations in Pinehurst are assumed to be the same as last measured in 1974, and thus probably overestimates the current risk

Figure 6.4
Noncarcinogenic Risk For Hematopoietic Effects (Anemia)
(Risks associated with Zn intakes)

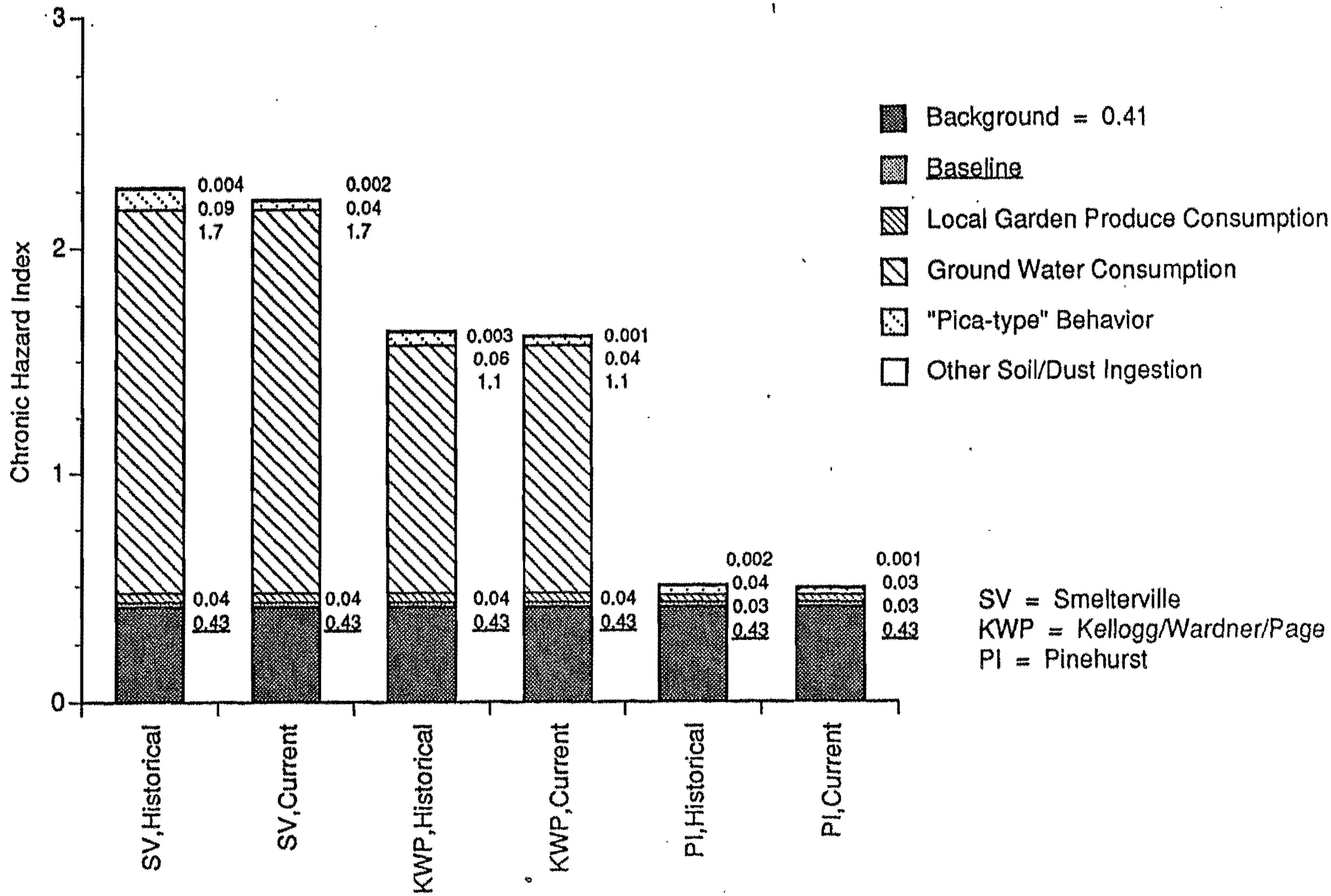
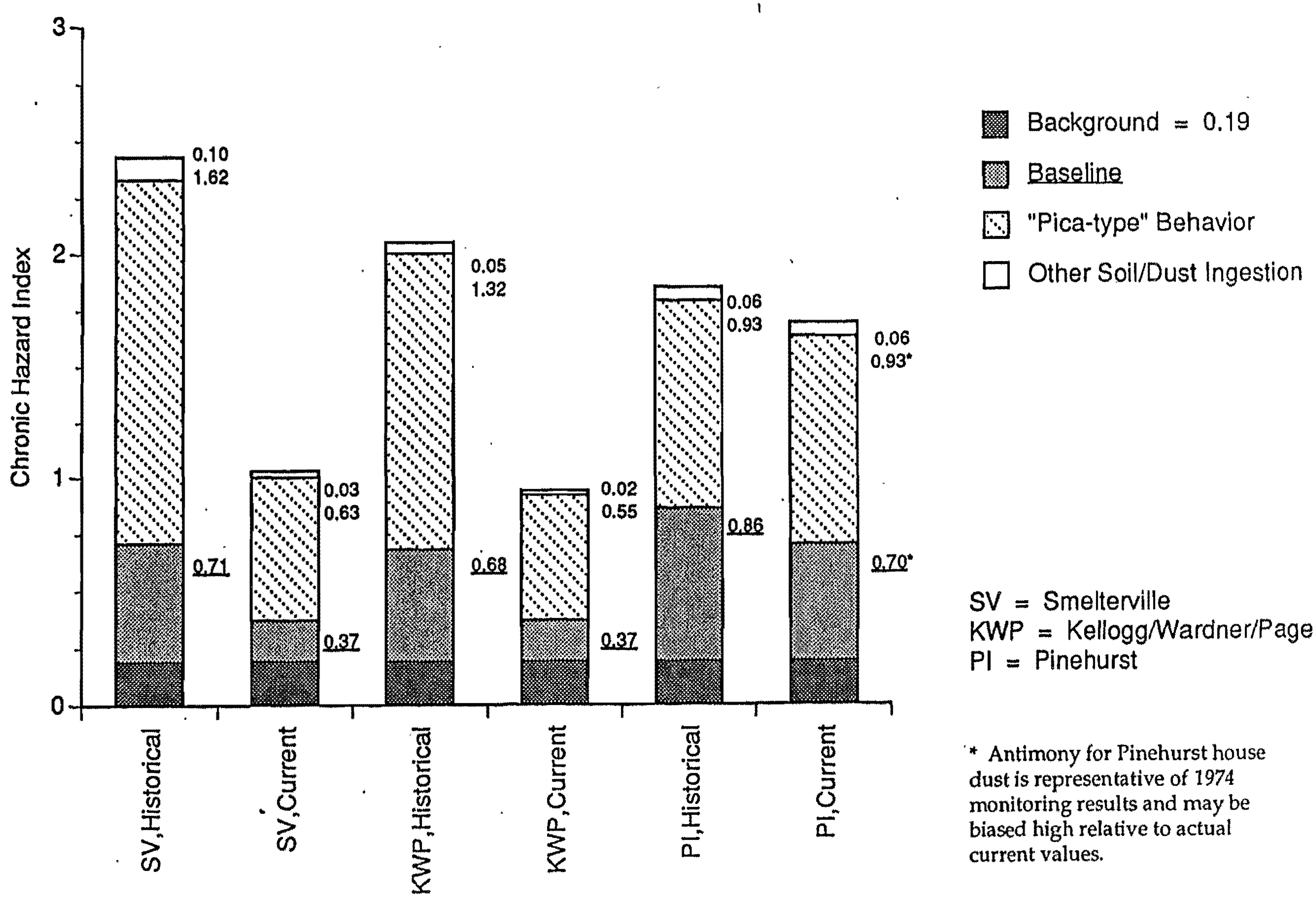


Figure 6.5
Total Noncarcinogenic Risk For Gastrointestinal Toxicity
(Risks associated with Cu and Sb intakes)



associated with house dust ingestion in Pinehurst. The certainty associated with risk estimates to gastrointestinal toxicity is low due to low confidence in the oral RfD for antimony.

Risk to **renal disease** due to baseline **cadmium** and **mercury** exposures and consequent intakes via the oral route, in terms of an $HI_{(Cd + Hg)}$, is determined to be acceptable ($HI_{(renal\ disease)} < 1.0$). Figure 6.6a and b presents the estimated HIs for renal dysfunction due to cadmium and mercury intakes via the oral route. Approximately 60 to 90 percent of baseline and background cadmium and mercury intakes are due to national market basket produce consumption with a significant portion of the remaining intake largely due to house dust ingestion. Excess risk to renal disease could occur from the combination of baseline exposures plus local garden vegetable consumption ($HI_{(renal\ disease)} = 0.98_{(current,\ Pinehurst)}$ to $1.4_{(historical,\ Smelterville)}$) or from baseline exposures plus groundwater consumption ($HI_{(renal\ disease)} = 3.5_{(current,\ Kellogg/Wardner/Page)}$ to $19_{(historical,\ Smelterville)}$), with cadmium contributing > 98% of the estimated toxicity. "Pica-type" behavior, resulting in ingestion of extreme amounts of soil and dust, could yield excess risk for renal damage, with generally equal contributions of toxicity from cadmium and mercury. Risk to renal disease resulting from baseline and incremental exposures is estimated as lower limits since risk is not characterized for concomitant and excess lead exposures. Estimates of adverse health risk associated with cadmium are low relative to potential risk since groundwater concentrations used for intake estimates are based on dissolved metals and not total or total recoverable. Because the confidence level associated with the oral RfD for cadmium is high, a relatively high degree of certainty is associated with oral risk estimates for renal disease as lower limits.

Table 6.6 summarizes the exposure routes, scenarios and potentially high risk activities that could result in unacceptable risks to noncarcinogenic disease due to chronic exposures to site contaminants of concern. Unacceptable risk is determined to be where $HI_{(specific\ disease)} \geq 1.0$ and when $HI_{(specific\ disease)}$ is different from that associated with

Figure 6.6a
Noncarcinogenic Risk For Renal Toxicity
(Risks associated with Cd and Hg intakes)

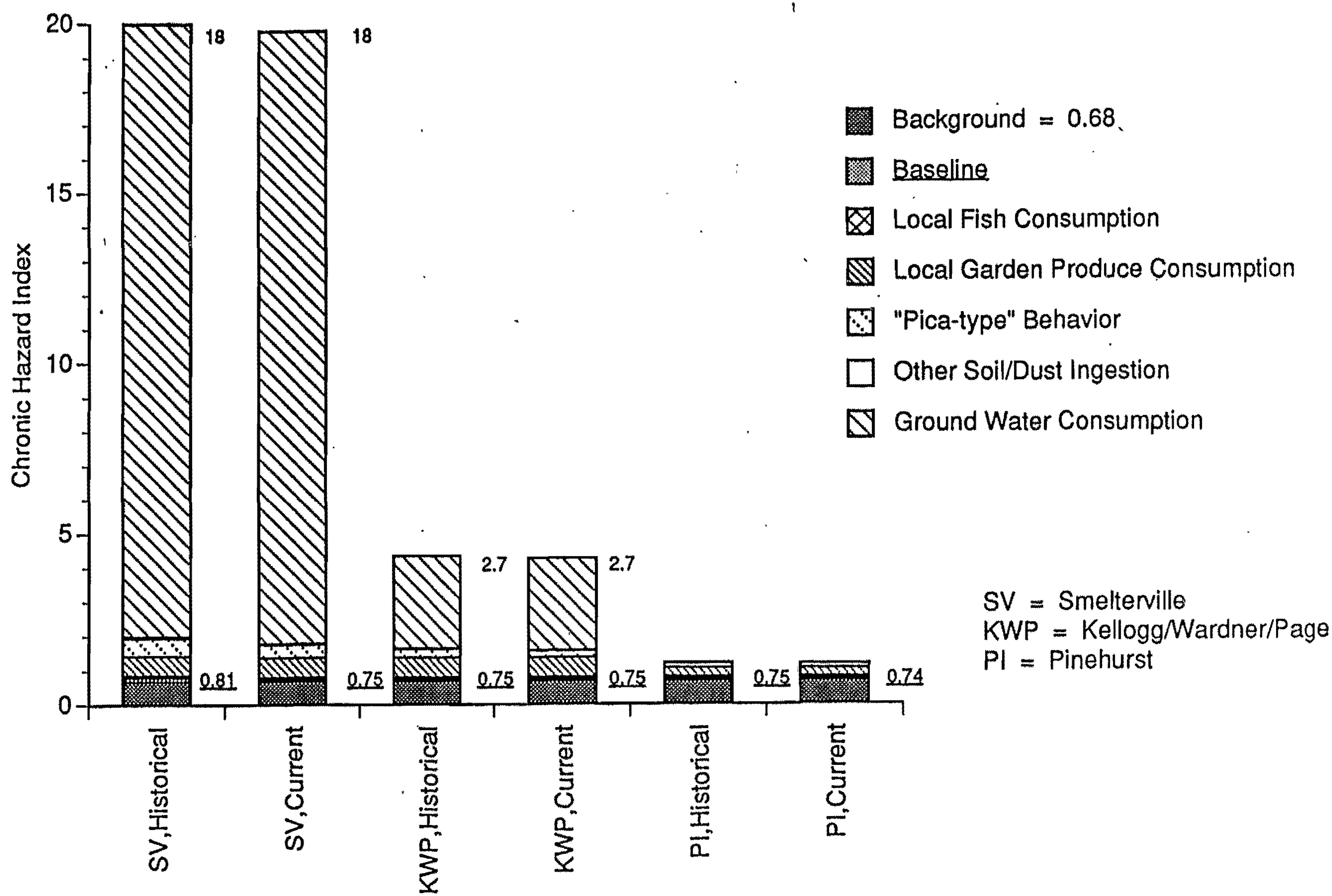


Figure 6.6b
Noncarcinogenic Risk For Renal Toxicity
(Risks associated with Cd and Hg intakes)
(Same as Figure 6.6a with ground water contribution removed)

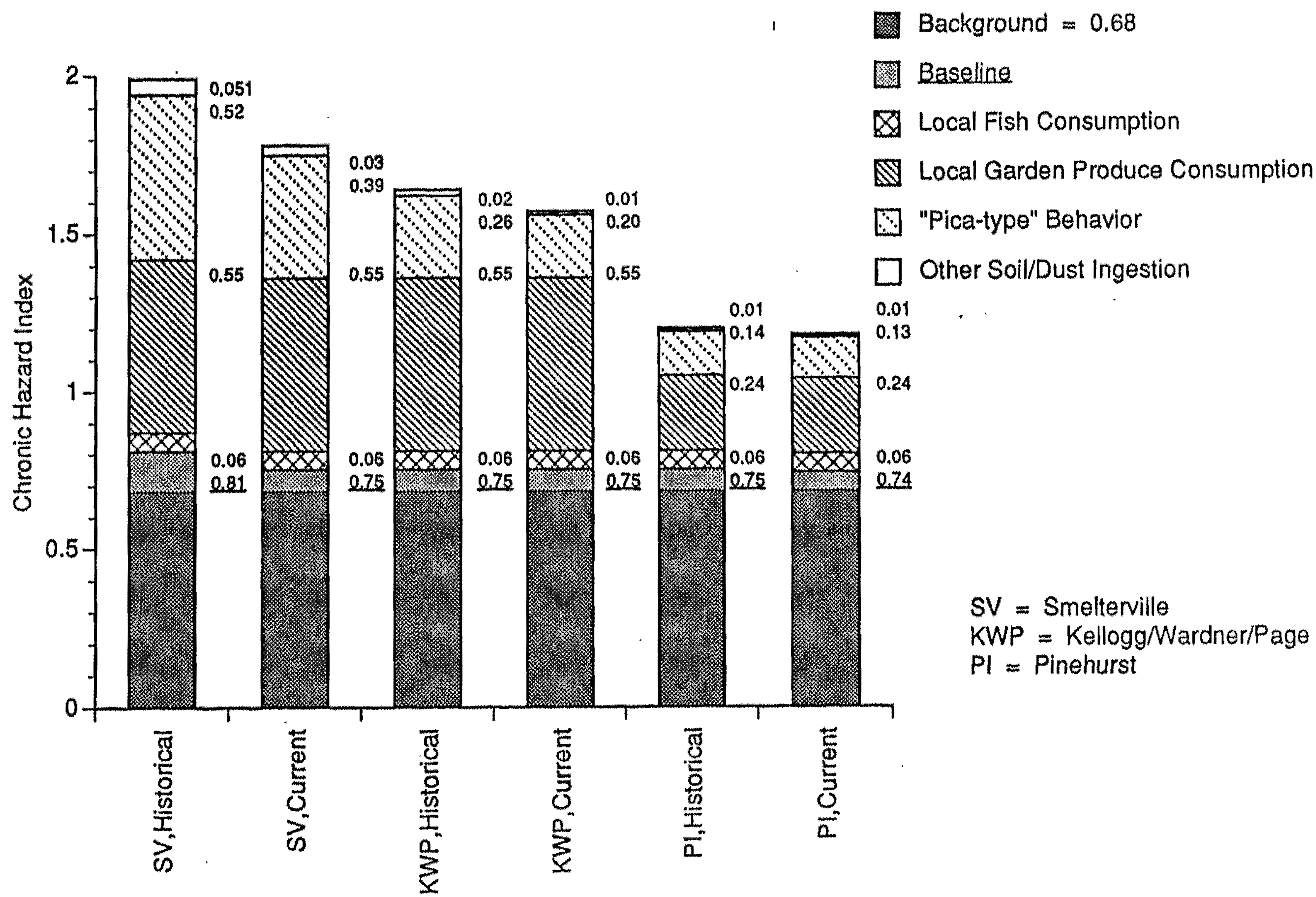


Table 6.6
Summary of Exposure Routes, Scenarios and Potentially High Risk Activities that Could Result in Unacceptable Chronic Risk to Noncarcinogenic Disease

Skin lesions due to arsenic exposures:

Historical, Smelterville -	baseline plus groundwater consumption, HI ≥ 1.3
Current, Smelterville -	baseline plus groundwater consumption, HI ≥ 1.1

Anemia due to zinc (and lead*) exposures:

Historical, Smelterville -	baseline plus groundwater consumption, HI ≥ 2.1
Historical, Kellogg/Wardner/Page -	baseline plus groundwater consumption, HI ≥ 1.5
Current, Smelterville -	baseline plus groundwater consumption, HI ≥ 2.1
Current, Kellogg/Wardner/Page -	baseline plus groundwater consumption, HI ≥ 1.5

Gastrointestinal irritation due to antimony and copper exposures:

Historical, Smelterville -	baseline plus "pica-type" behavior, HI = 2.3
Historical, Kellogg/Wardner/Page -	baseline plus "pica-type" behavior, HI = 2.0
Historical, Pinehurst** -	baseline plus "pica-type" behavior, HI = 1.8

Renal dysfunction due to cadmium and mercury (and lead*) exposures:

Historical and Current for both Smelterville and Kellogg/Wardner/Page -
baseline plus local garden produce consumption, HI ≥ 1.3 - 1.4
baseline plus groundwater consumption, HI ≥ 3.5 - 19

Historical and Current, Smelterville -	baseline plus "pica-type" behavior, HI ≥ 1.1 - 1.3
Historical, Kellogg/Wardner/ Page -	baseline plus "pica-type" behavior, HI ≥ 1.0

NOTE:

"Pica-type" behavior is associated with extreme soil and dust ingestion rates exhibited by some children of ages 2 through 6 years.

* While an RfD is not available for lead, extreme lead exposures can contribute, among other pathologies, to anemia and renal disease.

**Antimony in Pinehurst house dusts is represented by 1974 monitoring results and may be in excess of actual current concentrations.

background exposures. Sub-chronic exposures and consequent intakes could result in unacceptable sub-chronic toxicities, especially for consumption of local garden produce and extreme soil/dust ingestion ("pica-type" behavior), and when chronic (lifetime) HIs are determined to be less than 1.0.

6.2.2 Sub-chronic Lead Exposures

Population exposures to environmental lead is of special concern to young children and pregnant women (as surrogates to the fetus) due to their susceptibilities and sensitivities to low doses of lead (see Sections 3.5.1.5 and 5 in the PD for detailed presentation). Primary exposure information and toxicological, clinical and epidemiological evidence from health surveys suggests that sub-chronic exposures to children and pregnant women is the primary concern in the RI/FS area regarding lead exposures.

The traditional approach for risk characterization of metal exposures is by comparison of chronic and sub-chronic intakes to an RfD. This method is currently not appropriate for lead because an acceptable RfD is not available. Most information and research concerning the adverse health effects of lead have been expressed in terms of the blood lead level as an indicator of recent and sub-chronic exposures. Potential health risk to lead exposures is expressed in terms of a range of blood lead levels associated with adverse health effects. Actual blood lead survey data are available for the site since 1974 and are used to assess current health risk to the childhood population.

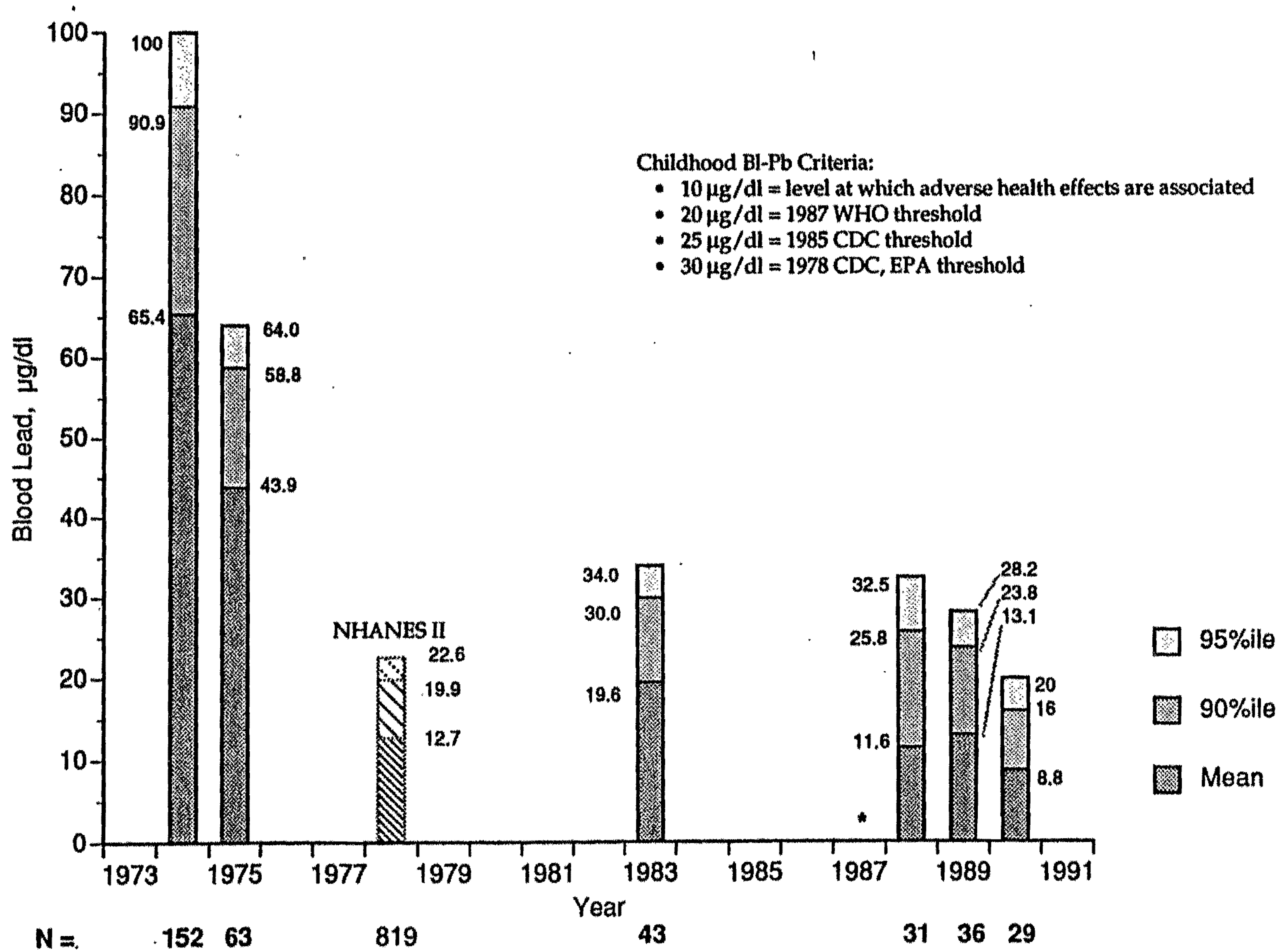
The exposure analysis for lead is accomplished in a manner consistent with the methodology employed by the USEPA in its review of the National Ambient Air Quality Standard (NAAQS) and the Federal drinking water standard for lead. These evaluations determine how and to what extent reductions in environmental lead concentrations could affect reductions in population blood lead levels. Lead exposures and health-based blood lead targets are evaluated by a dose-response analysis for childhood blood lead levels using an integrated uptake/biokinetic dose-response model developed by the USEPA

Environmental Criteria and Assessment Office (ECAO). The dose-response model and associated input parameters are selected, evaluated and validated here employing site epidemiologic data, which is presented in Appendix C. Application of the dose-response model to evaluate historical populations and the no-action remedial alternative is unnecessary since site-specific population blood lead values are available. The model will be used for determination of remedial goals for the protection of public health and for the evaluation and selection of remedial alternatives.

Considerable amounts of environmental and health survey data are available for this site and are presented in detail in the PD (JEG et al., 1989). A summary of childhood blood lead distributions for each of the Bunker Hill communities are graphically presented in Figures 6.7 through 6.11. For comparison, the blood lead distributions for children (white, rural and ≤ 5 years of age) examined nationally in the National Health and Nutrition Evaluation Survey (NHANES) (1984) Study for the period 1976 through 1980 are also noted. Blood lead statistics from the NHANES show an arithmetic mean of 13.5 µg/dl, geometric mean = 12.7 µg/dl, and a geometric standard deviation of 1.42. Additional childhood blood lead distributions and associated statistics for the site are presented in Figures A6.1 through A6.7 and Table A6.1 in Appendix A, and Figures C1 through C12 in Appendix C. For 1975 to 1980 the Bunker Hill community mean blood lead levels were 2.1 to 2.9 times greater than off-site background. Estimated chronic intakes for lead during the current scenario (from Table 5.12) were approximately 2.1 to 3.6 times greater than background, similar to the increase for blood leads. While blood lead levels at the site have decreased since 1974, the variance, in terms of the geometric standard deviation, has actually increased from 1.39 in 1975 to 1.81 for children ≤ 3 years of age in 1983. The larger variability for recent years suggests that multiple rather than single sources of lead are probably impacting childhood exposures.

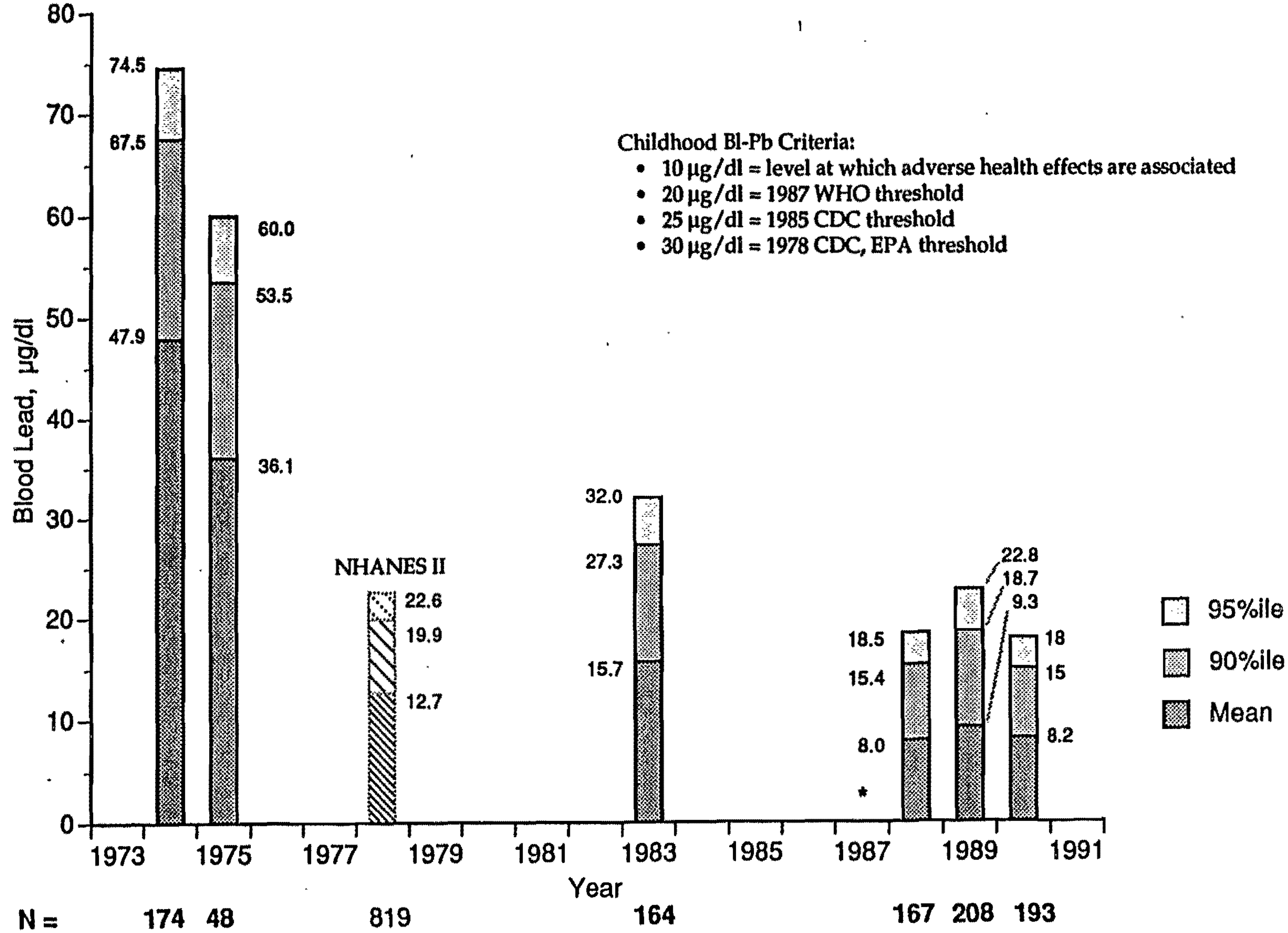
While total lead exposures and consequent intakes have been reduced in recent years compared to population exposures experienced during the period of active smelter operations, multiple but small sources are currently responsible for population exposures.

FIGURE 6.7
Smelterville Childhood Blood Lead Distributions by Year



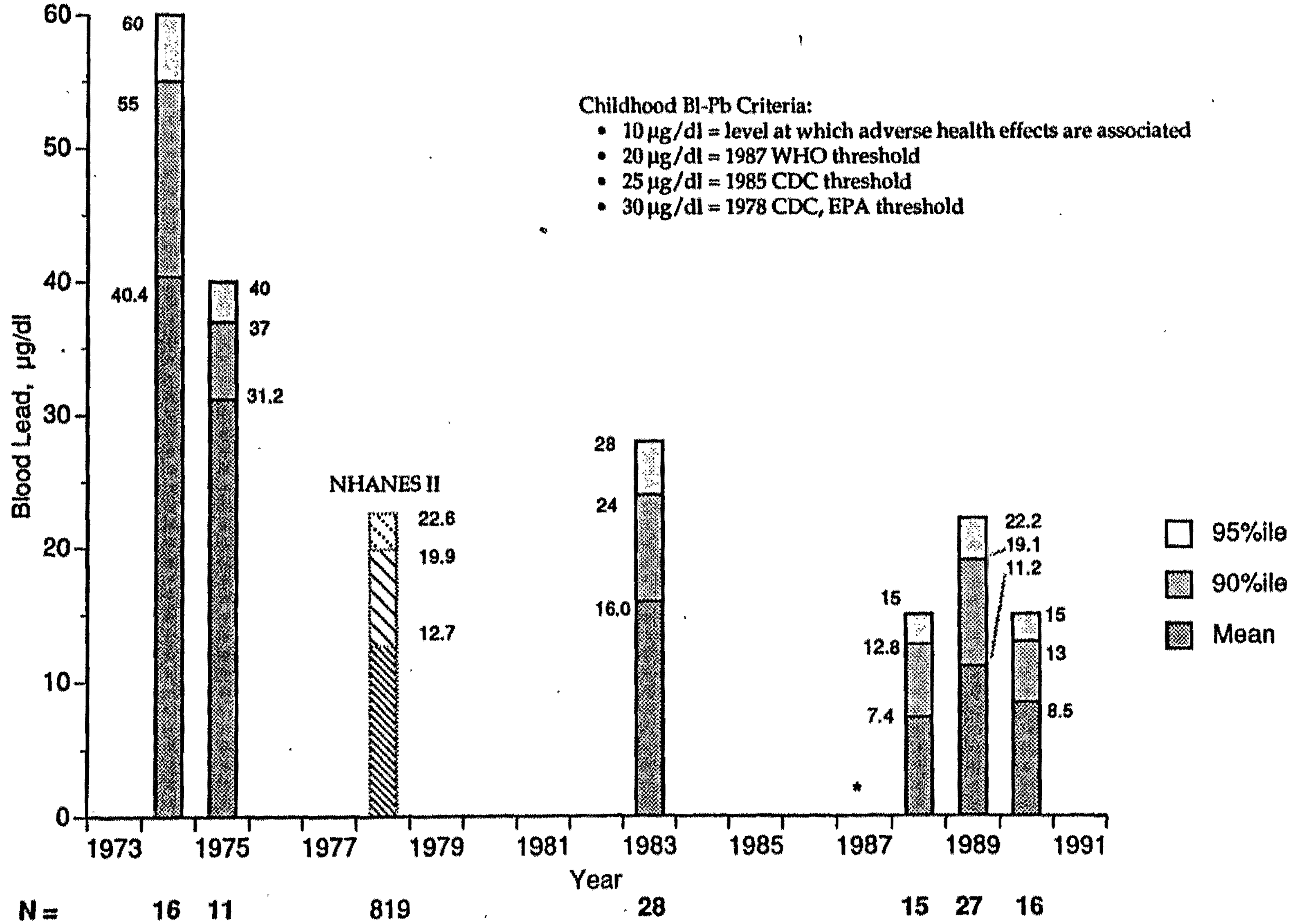
* U.S. mean blood lead for 1987 is predicted to be 7 μg/dl (Battelle,1990).

FIGURE 6.8
Kellogg Childhood Blood Lead Distributions by Year



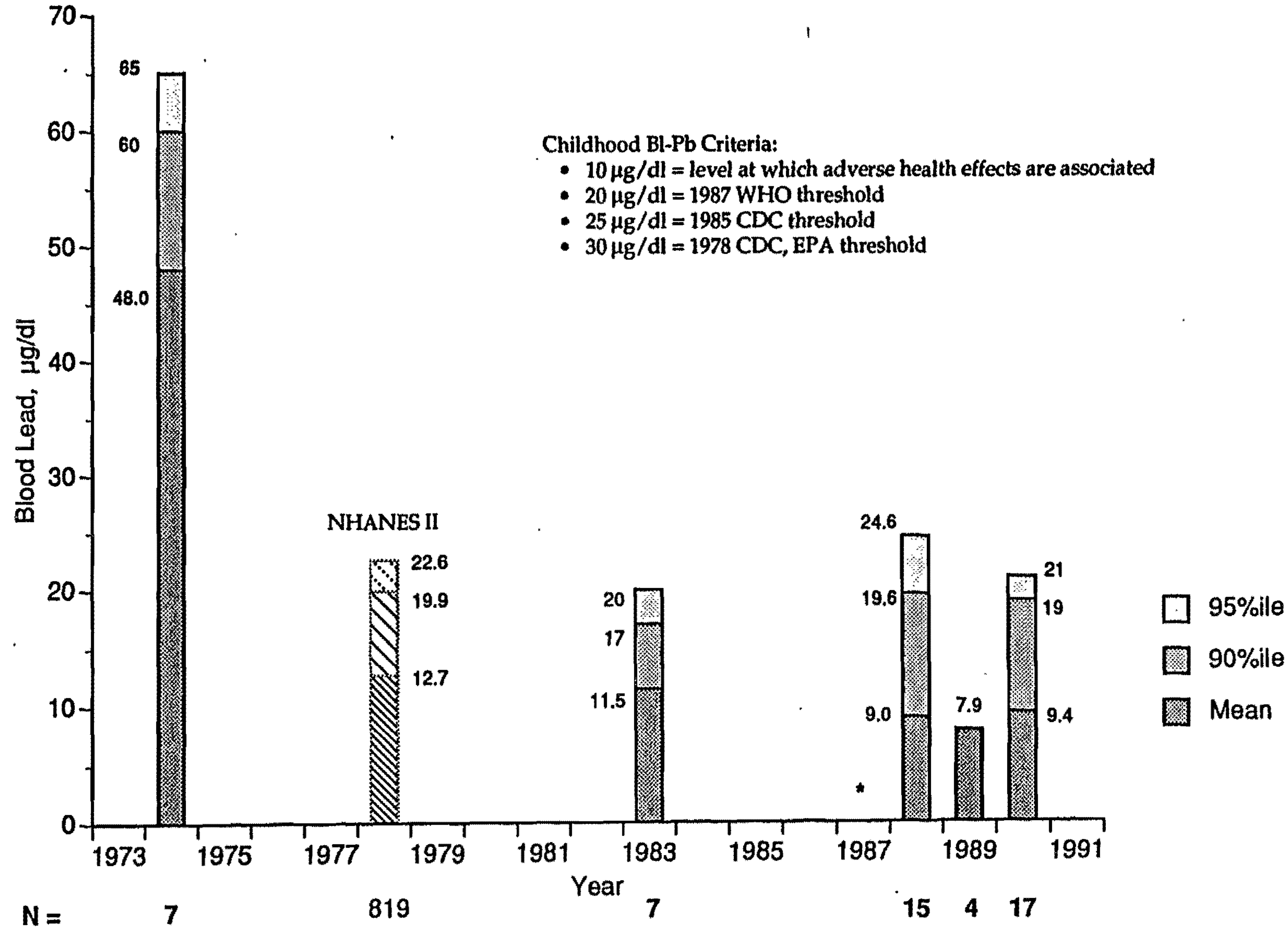
* U.S. mean blood lead for 1987 is predicted to be 7 µg/dl (Battelle,1990).

FIGURE 6.9
Wardner Childhood Blood Lead Distributions by Year



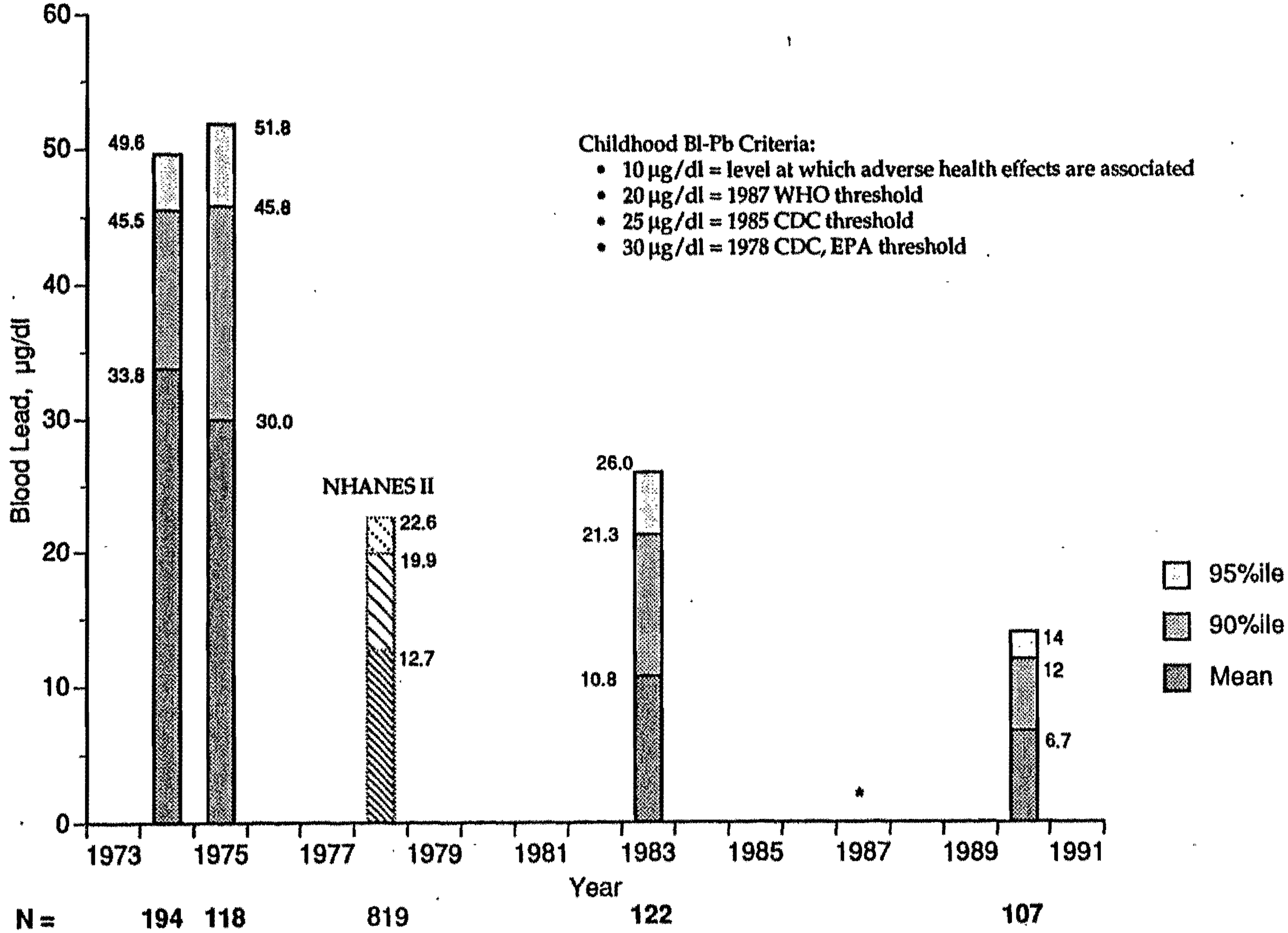
* U.S. mean blood lead for 1987 is predicted to be 7 µg/dl (Battelle,1990).

FIGURE 6.10
Page Childhood Blood Lead Distributions by Year



* U.S. mean blood lead for 1987 is predicted to be 7 µg/dl (Battelle,1990).

FIGURE 6.11
Pinehurst Childhood Blood Lead Distributions by Year



* U.S. mean blood lead for 1987 is predicted to be 7 µg/dl (Battelle, 1990).

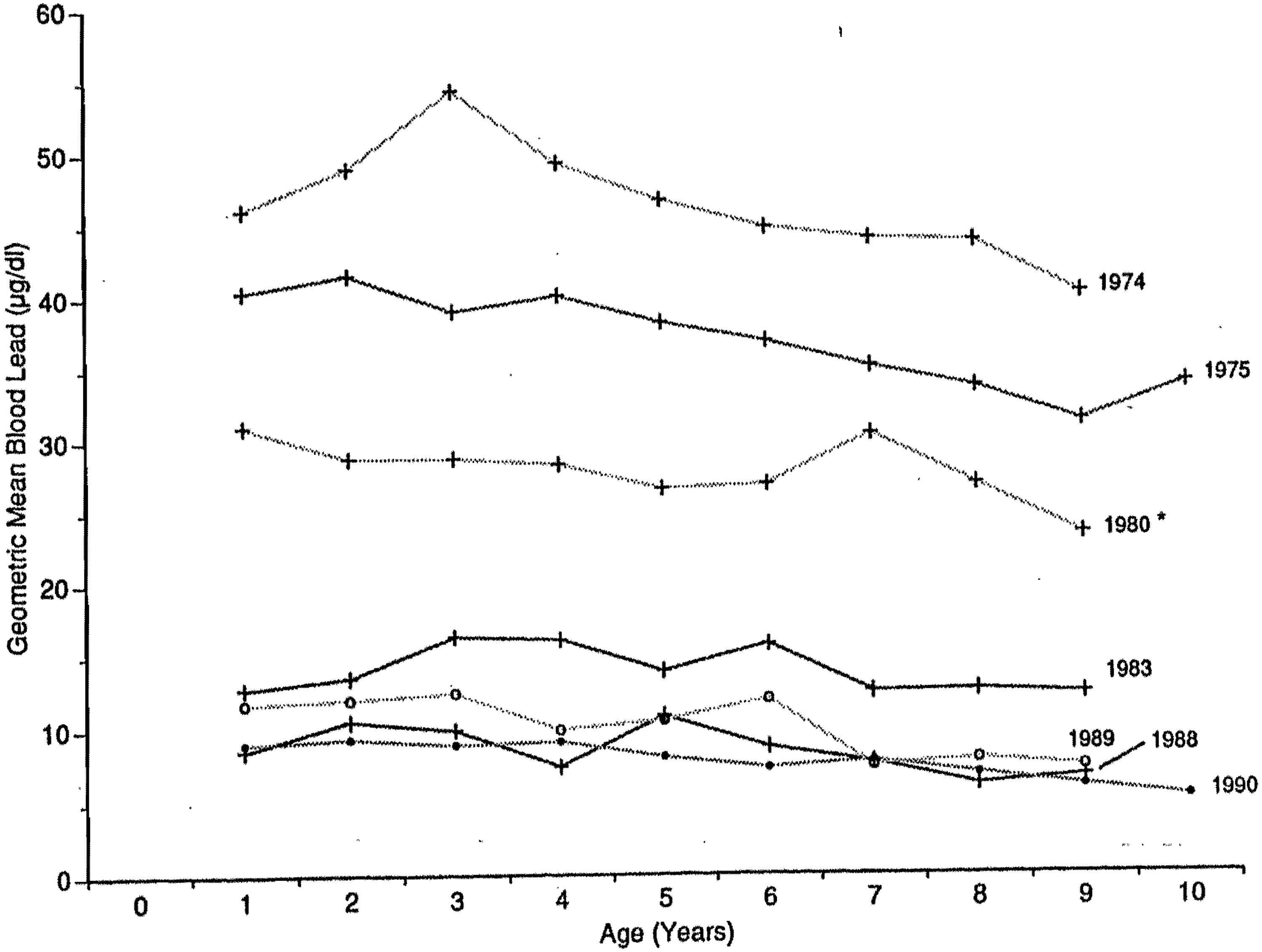
These sources have always been present, but were overwhelmed during active smelter operations by large emissions of lead contaminated fugitive dusts and stack emissions. Primary contaminant sources responsible for adverse exposures to the residential population prior to 1981 were related to active smelter emissions, where post-closure and current sources, while reduced in total strength, are multiple and residual due to past accumulations of contaminated solids and wastes.

Significant exposures and consequent absorption of lead have occurred on site over the years. Lead toxicity was extreme during the 1970s (see Section 5 in the PD) with notable improvement following closure of the Bunker Hill operations in 1981 and further reduction in blood lead levels after 1983. Figures C1 through C6 in Appendix C and Figure 6.12 show the changes in blood lead distributions and mean blood lead levels by age as a function of time. Factors contributing to a reduction of blood lead levels may include the following:

- Reduction in environmental media lead concentrations,
- Reduced environmental lead loadings,
- Dietary lead intake reduction,
- Shift in the types of chemical species and bioavailability of lead,
- Increased physiologic clearance (excretion) rates,
- Improved nutritional intakes and general health status, and
- Intake reductions achieved through denying access to sources and the increase in family and personal hygiene practiced in the community. This would be reflected in improved hygienic (housekeeping) practices, increased vigilance, parental awareness, and special consultation regarding remediation practices such as lawn care, removals, restrictions, etc.

The blood lead threshold of concern has continued to decrease over time as new information demonstrates adverse health effects at lower levels. These changes have

FIGURE 6.12
Bunker Hill Populated Areas
Geometric Mean Blood Lead for Ages ≤ 10 Years
Smelterville, Kellogg, Wardner, Page and Pinehurst



* Arithmetic mean blood leads available only for 1980

been summarized in USEPA, 1986a and ATSDR, 1988. In 1978, the USEPA, in association with CDC, identified 30 μg/dl as a target threshold for the protection of children against the adverse health effects of absorbed lead. The CDC lowered the target threshold in 1985 to 25 μg/dl as a level above which medical intervention is advised. The World Health Organization in 1987 identified a blood lead threshold at 20 μg/dl. Recent information indicates that no threshold has been detected at which health effects due to absorbed lead are not observed. The USEPA and ATSDR have indicated that blood lead levels around 10-15 μg/dl or even lower in young children may be argued as becoming biomedically adverse. It has been noted that risks associated with absorbed lead are likely in the range of 10-15 μg/dl and less certain below 10 μg/dl. The USEPA Clean Air Scientific Advisory Committee (CASAC) (USEPA, 1990a) suggests that 10 μg/dl is the maximum blood lead permissible for all members of sensitive groups, and not to be representative of a population mean or median value. CASAC strongly recommends a public health goal of minimizing the lead content of blood to the extent possible through reduction of lead exposures in all media of concern. Recently, the CDC has indicated that consideration is being given for identifying 10 μg/dl as a community action level and 15 μg/dl as the level requiring child placement in a follow-up health program (USEPA, 1990b).

Greatest attention is given to young children with blood lead levels above 10 μg/dl. This is consistent with the concerns for adverse health effects to young children due to low level lead exposures. A detailed presentation of lead health effects and a comprehensive toxicological profile is found in Sections 3.5.1.5 and 5.4 of the PD (JEG et al., 1989). Review of the industrial post-closure (since 1981) blood lead survey data indicates that 50 (13.7%) children in 1983, 7 (3.1%) children in 1988, 8 (2.9%) children in 1989, and 2 (~1%) children in 1990 required medical intervention due to exceedance of the 1985 CDC criteria. With respect to the 10 to 15 μg Pb/dl range of concern for children, survey data indicates that 49.2% of the site children exhibited ≥ 15 μg Pb/dl blood and 80.5% ≥ 10 μg Pb/dl blood in 1983; 15.4% ≥ 15 μg Pb/dl and 45.2% ≥ 10 μg Pb/dl in 1988;

25.8% ≥ 15 μg Pb/dl and 50.6% ≥ 10 μg Pb/dl in 1989; and 11.3% ≥ 15 μg Pb/dl and 37.0% ≥ 10 μg Pb/dl blood in 1990.

Some of the health effects of low level lead exposures are reported to be long-term and possibly permanent (see Sections 3.5.1.5 and 5.0 in the PD for a detailed presentation). Lead exposures during infancy and childhood, that resulted in an average blood lead level of 34 μg/dl, are reported to be associated with long-term central nervous system deficits that persist into young adulthood (Needleman et al., 1990). Early childhood lead exposures were found to be significantly associated with diminished academic success relative to a *lower blood lead* reference group, specifically lower class standing in high school, increased absenteeism, lower vocabulary and grammatical-reasoning scores, poor hand-eye coordination, extended reaction times, slow finger tapping, and increased school-drop out rate (Needleman et al., 1990). A review of past exposures and health survey data at the Bunker Hill site indicates that during extreme exposures in the early to mid-1970s up to 80% of the children exhibited blood lead levels that are associated with adverse neurobehavioral development which persists into young adulthood. Additional concern for past lead exposures (prior to smelter closure in 1981) is due to the potential release of lead from normal bone resorption during pregnancy and lactation and the resultant pre- and post-natal exposures to children who are born today of mothers who were exposed as children in the 1970s.

In the absence of cleanup standards for lead contaminated environmental media, a risk assessment approach using a modeling technique for blood lead response has been investigated as a means of establishing multi-media cleanup levels for lead. This approach has been used by the EPA's OAQPS to establish the NAAQS for lead, and is being considered by the Environmental Criteria and Assessment Office (ECAO) as a method for determining cleanup levels for lead in soils and dusts. The integrated uptake/biokinetic dose-response model is applied here to relate childhood blood lead levels to contaminated media exposures. Model parameters are selected and validated using the site-specific data base. The validated model and associated input parameters are used for the evaluation of remedial goals and potential cleanup alternatives for lead contaminated soils and house dusts.

The integrated uptake/biokinetic dose-response model is a four-compartment first order kinetic model of lead metabolism that has been developed from data obtained in controlled single dose and chronic lead exposures of infant and juvenile baboons. Dynamic blood measurements and steady state blood and organ lead measurements were closely fitted to predict equilibrium concentrations of lead in blood, liver, kidney and bone (the four compartments in which 95% of total body lead is contained). The model utilizes a linear relationship between absorbed lead (from multiple media) and blood lead at levels of uptake from 10 to 100 μg Pb/day in terms of age-specific reciprocal clearance rates or physiologic response coefficients (presented in Appendix C). Linearity and greatest predictive power of the model is at blood lead levels less than 30-40 μg/dl; progressively greater intakes are required to yield equal and successive incremental increases in blood lead levels above 30-40 μg/dl. This relationship of reduced slopes between blood lead level and intake at higher blood lead levels may be due to nonlinear renal clearance, distributional non-linearities due to differences in lead binding sites in different tissues, and/or to a sizeable pool of mobile lead in bone maintained independently of uptake (USEPA, 1989e).

The model is flexible and allows the use of site-specific input data as well as default values for critical input parameters. A test of model sensitivity to input parameters has shown that in most environments, including Bunker Hill, where residual lead contamination is associated with soils and dusts, the critical input parameters are dietary lead intake, soil and dust ingestion rate, gastrointestinal absorption of lead, and the variance in blood lead response (in terms of the geometric standard deviation about the mean blood lead) (USEPA, 1990b). Site-specific epidemiological data has been used in Appendix C to test and validate critical input parameters to the model.

The integrated uptake/biokinetic dose-response model is shown to be accurate for predicting childhood mean blood lead response at the Bunker Hill site given the appropriate environmental media lead concentrations and site-specific input parameters. Blood lead variances for the site population are approximately log-normally distributed, and a population geometric standard deviation can be applied to the predicted mean blood lead value to describe observed distributions. Application of the dose-response model with site-specific input parameters has been demonstrated to predict blood lead levels for the site population over a range of environmental conditions. The integrated uptake/biokinetic dose-response model for lead with use of appropriate site-specific input parameters is suitable for evaluating the effectiveness of selected remedial goals.

Input parameters to the dose-response model that most accurately describe recent (since 1983) childhood (ages $\leq$ 9 yrs) blood lead levels at the Bunker Hill site are:

- Air lead mean concentration = 0.14 $\mu g/m^3$, yielding 0.3 μg Pb/day uptake
- Lead intake from diet = 10 μg/day, yielding 3.5 μg Pb/day uptake
- Soil/Dust ingestion rate = 55-75 mg/day, and a mean GI Pb absorption rate = 20%; yielding 21-27 μg Pb/day uptake from soil and house dust
- Community mean daily lead uptakes = 26 $\mu g/day_{(1988)}$ to 30 $\mu g/day_{(1989)}$
- Community blood lead geometric standard deviation (GSD) = 1.67 - $1.72_{(1983-1989)}$

Model results suggest that from 81 to 87 percent of the total lead uptake for the typical child in Smelterville, Kellogg, Wardner and Page during 1988 and 1989 is attributed to contaminated residential soil and house dust ingestion. The model predicts that application of a 500-1000 $\mu g/gm$ (ppm) soil and house dust lead cleanup level, which is consistent with recent USEPA guidance concerning soil lead cleanup levels at Superfund sites, would yield a blood lead response of less than 10 μg/dl for 97 to 100 percent of the childhood population. This prediction assumes that soil replacement values are less than ~100 μg/gm lead (USEPA, 1989a).

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7.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The Populated Areas of the Bunker Hill site comprise approximately 20% of the 21 square mile area located in the Coeur d'Alene mining district of northern Idaho. The site encompasses a non-operational primary lead/zinc smelting complex and includes five towns, a mine/mill facility, and contaminated river drainage. It has been divided into populated and non-populated portions for Remedial Investigation/Feasibility Studies (RI/FS). The Populated Areas consists of four cities and one unincorporated community with approximately 5,000 residents and includes all residential, commercial, and municipal public properties in the site.

Large amounts of potentially toxic contamination exist on the site as a result of a century of mining and smelting activity and associated waste discharges. There are health concerns with respect to both the volume and toxicity of the residual wastes. Primary contaminants of concern, relative to human health risk in the Populated Areas, include **antimony, arsenic, cadmium, copper, lead, mercury**, and **zinc**. Contamination is ubiquitous and is found in a wide range of concentrations in residential yard soils, interior dusts, right-of-ways, commercial properties, surface and groundwater, and air particulate matter. Exposure of sensitive sub-populations to these media can result in excess risk of both carcinogenic and non-carcinogenic disease. Remedial alternatives will likely include a combination of source removals, in-situ stabilization, access limitations and associated institutional controls.

The area has been documented as having a long history of lead-related health problems. The U.S. Environmental Protection Agency (USEPA), the Federal Centers for Disease Control (CDC), the Idaho Department of Health and Welfare (IDHW), the local Panhandle Health District (PHD), and the Agency for Toxic Substances and Disease Registry (ATSDR) have cooperatively conducted a number of environmental investigations, health surveys, and medical surveillance activities in the area. Public health intervention and medical follow-up programs have been in place over the last two decades to reduce excess lead absorption among area children. Continued health monitoring and response programs will likely be required as remediation activities proceed.

7.1 Baseline Characterization

Site characterization activities conducted in the Populated Areas RI have provided media specific contaminant concentrations for soils, dusts, airborne particulates, groundwater, surface water, and local foodstuffs. These data, presented in Section 2, indicate that several hundred private properties have metal contaminant levels in soils and dusts that could present a hazard to human health or the environment. Appropriate media concentrations were compared to State and federal applicable or relevant and appropriate requirements (ARARs) and to-be-considered material (TBCs). These materials are generally referenced as cleanup standards and/or guidelines for remedial actions at Superfund sites. Those chemical-specific ARARs and TBCs expected to be protective of human health were presented and compared to site data in Section 3. For several of the chemicals of concern and relevant pathways, no ARARs or TBCs exist. In those instances, the risk assessment process was used to determine and evaluate excess health risk in a baseline analysis, and for the evaluation of the effectiveness of selected cleanup goals as remedial alternatives. Exposure assessment and risk characterization were presented in Sections 5 and 6.

A comparison of site characteristics to chemical-specific ARARs and TBCs for the Populated Areas of the site, shows that contaminants in various media are found at concentrations that present a risk to human health. The available site-specific data, presented in Section 3.3, indicates that **groundwater** contaminant concentrations exceed State and federal groundwater and drinking water standards for cadmium, lead and zinc. Groundwater, in many parts of the site, is unsuitable as a drinking water source.

Comparison of chemical-specific ARARs and TBCs for **air** shows that the National Ambient Air Quality Standards (NAAQS) for particulate matter as PM_{10} was exceeded in Pinehurst (during winter months only) approximately 10% of the time in 1987 and about 3% of the time in 1988. The State air quality standard for maximum 24-hour concentration of particulate matter was exceeded 11% of the time in Pinehurst during 1987. These exceedances were observed only during winter months, and are reported to be associated with particulate emissions from wood burners. Current air quality standards for particulates and lead are being met for the remainder of the site. However, contaminant fate and migration analyses suggest that air transport of contaminated solids during episodic high wind events is a significant pathway. Reentrained dusts can contribute to the maintenance of metal contaminant levels in soils and house dust at critical receptor points in the Populated Areas of the site.

Pertinent guidance issued by the USEPA and CDC concerning excess **soil** and **dust** lead levels states that "lead in soil and dust exceeding 500-1,000 ppm (µg/gm) appear to be responsible for blood lead levels in children increasing above background levels". The USEPA has issued a directive establishing an interim soil cleanup level for total lead at 500-1,000 µg/gm. Site data indicates that approximately 95% of the residential yard soil lead concentrations in the most contaminated communities are equal to or greater than 500 µg/gm and approximately 85% ≥ 1,000 µg/gm. In the case of house dust lead concentrations, about 85% are ≥ 500 µg/gm, with about 65% ≥ 1,000 µg/gm.

Contaminant migration sampling and analysis indicate that dusts transported into the Populated Areas have concentrations ranging from 1,000 to 20,000 µg/gm lead. Deposition of these solids could result in similar short-term concentrations in house dusts and on other exposed surfaces. On an annual basis, concentrations in these media could be as high as 3,000 - 5,000 µg/gm. Continued accumulation of these solids could cause clean soils to be recontaminated to the 500 - 1,000 µg/gm range in as little as five to ten years.

A health advisory for **blood lead levels** issued by CDC in 1985 states that a blood lead level in children of 25 μg/dl or above indicates excessive lead absorption and constitutes grounds for medical intervention. However, significant health risks are associated with blood lead levels less than 25 μg/dl. The CDC level was chosen as a compromise between, then considered, acceptable risks and the practical and technical limits of lead screening programs. ATSDR and the USEPA have noted that adverse health effects are associated with blood lead levels as low as 10 μg/dl, and possibly less, due to pre- and post-natal exposures to children. The USEPA Clean Air Scientific Advisory Committee (CASAC) suggests that 10 μg/dl is the maximum blood lead permissible for all members of sensitive groups. CASAC suggests that levels in excess of the 10 - 15 μg/dl range warrant concern and strongly recommends a public health goal of minimizing the lead content of blood to the extent possible through reduction of lead exposures in all media of concern. Several of the adverse effects of lead on children are cumulative and irreversible and may result in subtle, long-term impairment in neurological and physical development. For 275 children tested for blood lead at the site in 1989, 3% showed blood lead levels equal to or greater than the 25 μg/dl CDC (1985) advisory level, approximately 26% of the children exhibited levels ≥ 15 μg Pb/dl, and 56% ≥ 10 μg Pb/dl blood. The highest blood lead level among those tested in 1989 was 41 μg/dl. In 1990, 255 children were tested in Smelterville, Kellogg, Wardner and Page. Forty percent (40%) of these children had blood levels in excess of 10 μg/dl and 14% exceeded 15 μg/dl. A significant percentage of the children tested currently exhibit blood lead levels exceeding a level reported to be associated with adverse health effects.

A **human health risk assessment** was conducted for site residents to evaluate endangerment when suitable ARARs were not available. The risk assessment determines and evaluates the potential risk that contaminated environmental media pose to current residents who have lived on site since 1983 (smelter post-closure) and since 1971 (smelter pre-closure). Two different lifetime scenarios were evaluated to determine if significantly greater risk was incurred by current residents due to exposures experienced during active smelter operations. These exposures were evaluated because residual and latent health effects associated with historical metal exposures may result in body burden accumulation and/or increased risk to chronic disease and cancer.

Baseline chronic risk was evaluated by utilizing mean media concentrations and determining exposures and consequent intakes for the typical or general population. Other high risk activities can result in heightened exposures that may require unique management. These activities were characterized as incremental exposures. Consequent risk (beyond typical baseline) was evaluated for the following potential high risk activities:

- Ingestion of local garden produce,
- Extreme dirt (soil and dust) consumption ("pica-type" behavior),
- Ingestion of "other" soils and dusts,
- Consumption of locally caught fish,
- Consumption of contaminated (site) groundwater, and
- Inhalation of air exhibiting extreme levels of contaminants.

Results of the chronic exposure and risk characterization presented in Section 6.1 indicates that excess (above background) **carcinogenic risk** is associated with baseline exposures and consequent intakes for arsenic and cadmium in air. Total baseline (70 year lifetime) risk to lung cancer, due to inhalation of arsenic and cadmium under current site conditions, is from 2 to 32 times greater than for off-site background. Under the historical scenario, risk to lung cancer was two to six times greater than the current scenario for the same communities. Baseline cancer risk estimates indicate that the typical population exceeds USEPA's acceptable range for cancer risk (10^{-6} to 10^{-4}). Baseline chronic and sub-chronic exposure evaluation and risk characterization are consistent with and supported by results of area health surveys and epidemiological studies. Lung cancer risk estimates are supported by tumor registry data showing excess respiratory cancer rates for the area.

Chronic and sub-chronic non-carcinogenic risk estimates presented in Section 6.2 indicate that excessive risk to disease is associated with consumption of residential soils and dusts, consumption of site groundwater, consumption of local garden produce, and "pica-type" childhood behavior. Site contaminants responsible for potential adverse health effects to the resident population include arsenic, cadmium and zinc in groundwater; cadmium and lead in local garden produce; and antimony, cadmium, lead and mercury in soil and dust. Increases in baseline risk to noncarcinogenic disease associated with historical metal exposures are primarily related to lead. From 1.3 to 1.6 times greater intake of lead is associated with the historical versus the current lifetime exposure scenario for this community. Estimates of chronic lead intakes for the site population indicate that from 2 to 6 times as much lead has been ingested and inhaled than for an off-site rural background population.

Lead health surveys of area children indicate that current **blood lead levels** for many children exceed levels at which adverse health effects are associated. During 1989, eight children required medical intervention due to exceedance of the 1985 CDC health criteria. In 1990, two of 362 children had blood lead levels exceeding 25 μg/dl. With respect to the 10 to 15 μg/dl Pb range of concern, survey data for Smelterville, Kellogg, Wardner and Page in 1989 indicates that approximately 25% of children $\leq$ 9 years of age exceeded a blood lead level of 15 μg/dl and ~50% exceeded 10 μg/dl. In 1990, 40% exceeded 10 μg/dl and 14% exceeded 15 μg/dl in these communities. In Pinehurst, 29% and 5% exceeded 10 μg/dl and 15 μg/dl, respectively. A review of past exposures and health survey data at the Bunker Hill site indicates that during extreme exposures in the early to mid-1970s, up to 80% of the children exhibited blood lead levels that are associated with adverse neurobehavioral development which persists into young adulthood. Additional concern for past lead exposures (prior to smelter closure in 1981) is due to the potential release of lead from normal bone resorption during pregnancy and lactation and the resultant pre- and post-natal exposures to children who are born today of mothers who were exposed as children in the 1970s.

7.2 Procedures for Determination of Remedial Goals

Risk management and remedial decisions in the Populated Areas of the site are dependent on site media contaminant concentrations and migration characteristics. Remedial actions are supported by conformance with ARARs and human health risk evaluations. In general, the most stringent of those considerations are applied for remedial planning purposes. The evaluation of both the baseline risk assessment and remedial goals require the determination of environmental contaminant concentrations that result in acceptable levels of risk. The remedial plan requires consideration of potential contaminant migration for institution of permanent solutions.

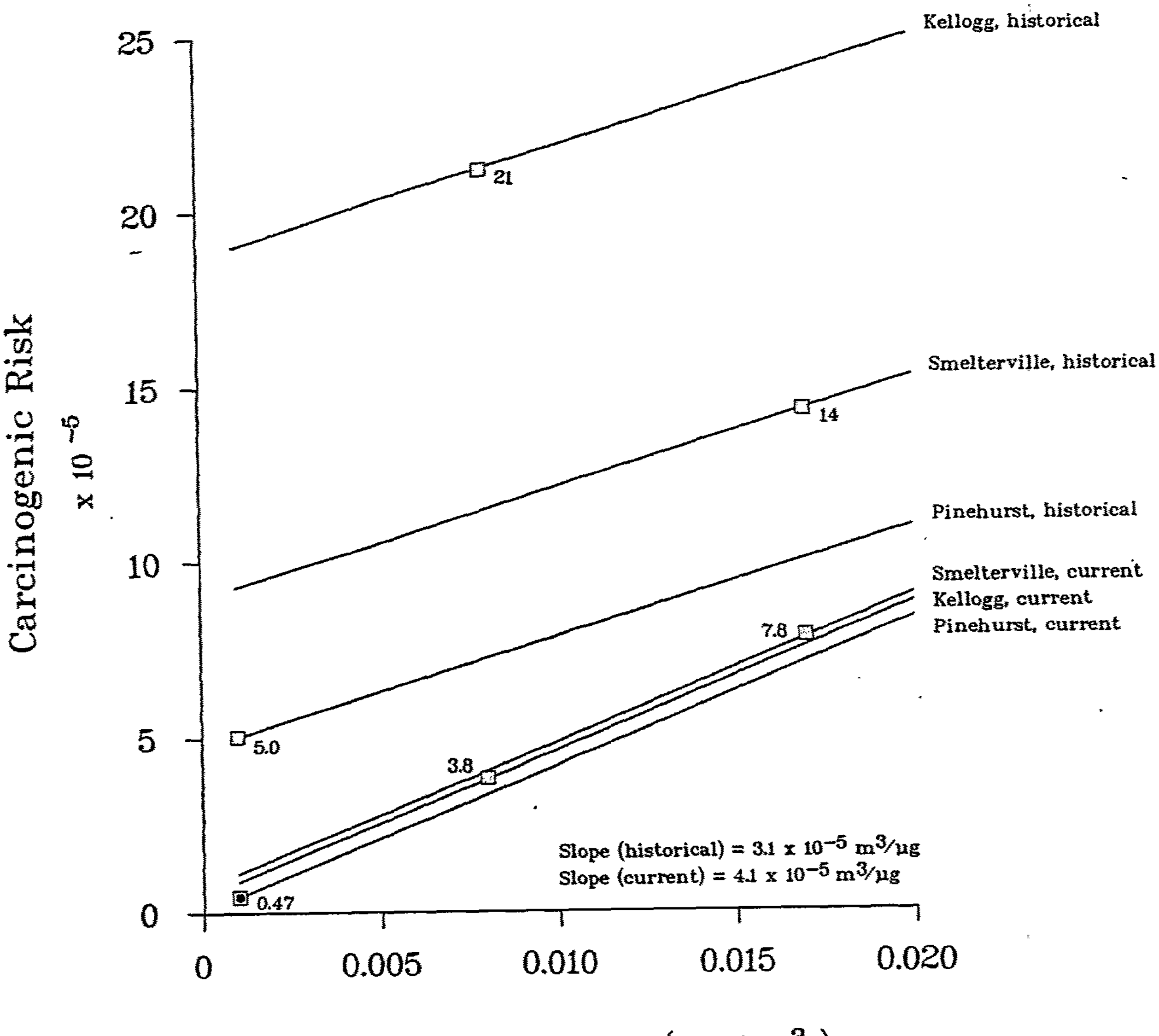
7.2.1 Consideration of Carcinogenic Risk

Baseline carcinogenic risk due to total intakes of arsenic and cadmium at the site is estimated to be slightly greater than that associated with estimated background exposures ($\sim 1 \times 10^{-3}$), that are primarily due to arsenic consumption of national market basket produce. Baseline carcinogenic risk in conjunction with the risk associated with the **consumption of site groundwater** in Smelterville and Kellogg due to arsenic intakes could result in a doubling of the risk associated with background exposures. Excess health risk due to arsenic in groundwater makes this source unsuitable for drinking in many areas of the site.

Total baseline risk to lung cancer due to **inhalation of arsenic and cadmium** is presented in Section 6.1 and Figure 6.2. Figures 7.1a and b present estimated risk to lung cancer as a function of arsenic and cadmium air concentrations after 1990. The plots take into consideration the exposures incurred in each community prior to 1991. Total risk to lung cancer is determined by summing the individual chemical risks. For example, total risk to lung cancer for a population born in Kellogg in 1971, employing most recent air concentrations for arsenic (0.008 $\mu g/m^3$) and cadmium (0.009 $\mu g/m^3$) under a no-action

Figure 7.1a

Lung Cancer Risk Associated with Arsenic in Air



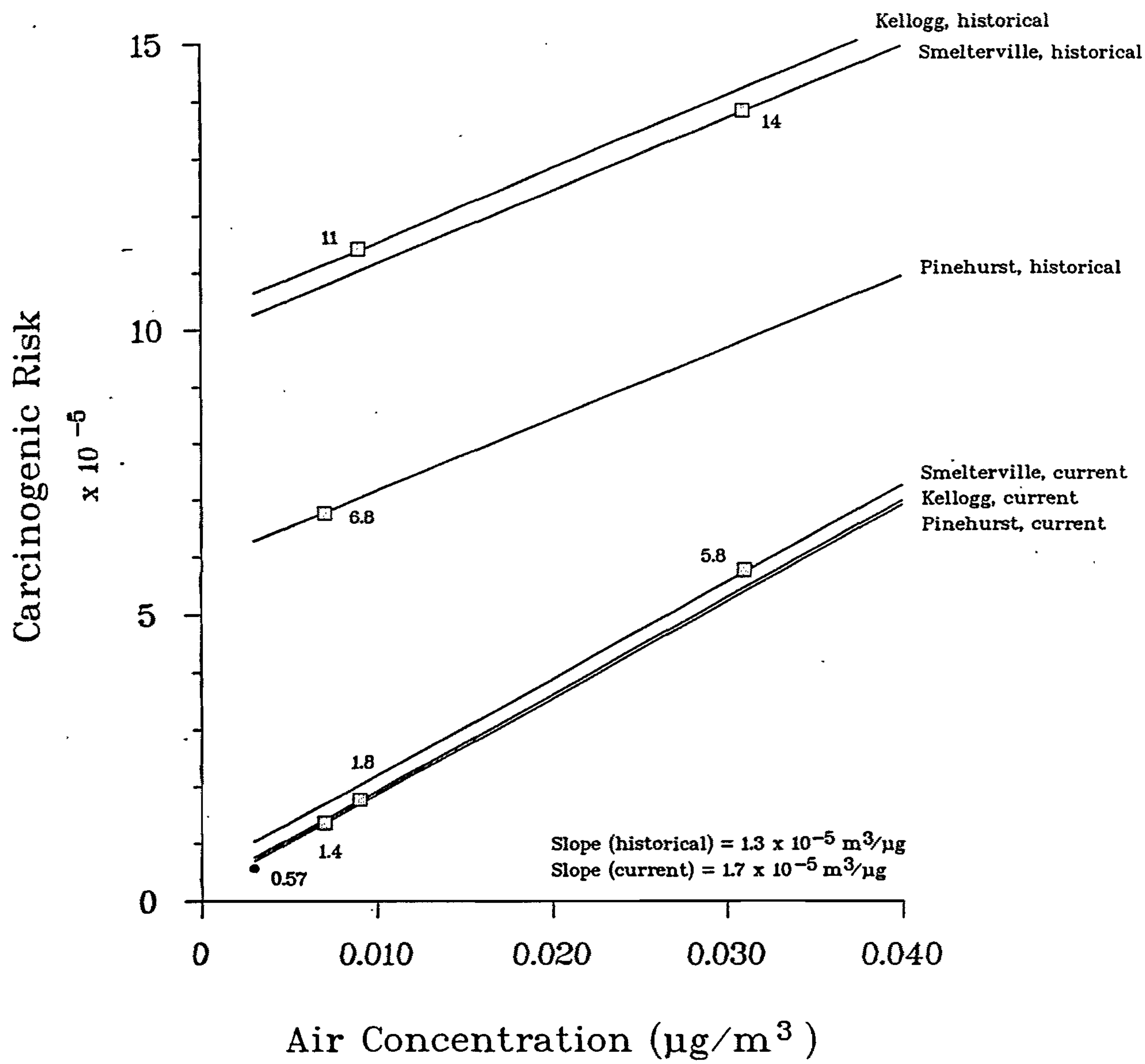
□ = risk under no–action alternative for each scenario.

● = background risk.

Note: total lung cancer risk = risk(arsenic) + risk(cadmium).
background mean air concentration = 0.001 μg As/m^3.

Figure 7.1b

Lung Cancer Risk
Associated with Cadmium in Air



☐ = risk under no-action alternative for each scenario.

● = background risk.

Note: total lung cancer risk = risk(arsenic) + risk(cadmium).
background mean air concentration = 0.003 µg Cd/m^3.

alternative, is 3.2×10^{-4} ($21. \times 10^{-5}_{(As)}$ + $11. \times 10^{-5}_{(Cd)}$). Alternatively, (for a population in Kellogg, born in 1971) the total risk for lung cancer would be 3.0×10^{-4} ($19. \times 10^{-5}_{(As)}$ + $11. \times 10^{-5}_{(Cd)}$) if mean air concentrations for arsenic and cadmium in Kellogg are reduced to 0.002 $\mu g/m^3$ and 0.002 $\mu g/m^3$, respectively. Acceptable levels of risk to lung cancer may never be attained at any future arsenic and cadmium air levels for those individuals who have had considerable historical and cumulative exposures. Tumor registry data supports the presence of an etiologic agent for the increased occurrence of respiratory cancers in the area. Rural Idaho background risk for lung cancer may not be attained by a population on site until a new generation of newborns is exposed to mean air concentrations of 0.001 $\mu g/m^3$ for arsenic and 0.003 $\mu g/m^3$ for cadmium, or some combination of concentrations yielding a total lung cancer risk of 1.0×10^{-5}, or less.

7.2.2 Consideration of Chronic Noncarcinogenic Risk

Chemical-specific noncarcinogenic risk estimates due to chronic exposures are presented in Table 6.4 for baseline risk and Table 6.5 for incremental risk due to potentially high exposure activities. Figures 6.3, 6.4, 6.5 and 6.6 graphically summarize the baseline and incremental risks for occurrence of skin lesions, hematopoietic (blood cell formation) effects, gastrointestinal toxicity and renal dysfunction. Unacceptable chronic non-carcinogenic risks (HI $\geq$ 1.0) are presented in Table 6.6. All estimated baseline non-carcinogenic risks for specific toxic endpoints and target organs due to oral intakes of site contaminants of concern have been determined to be acceptable ($HI_{(specific\ disease)} < 1.0$).

Unacceptable noncarcinogenic risk due to excess exposures to arsenic, cadmium and zinc could result from **consumption of site groundwater.** Excess metal intakes could cause skin lesions, anemia and renal disease due to arsenic, zinc and cadmium intakes, respectively. Adequate protection can be attained by achieving federal drinking water standards for groundwater as discussed in Sections 3.0 and 6.3.1.1.

Excessive soil and dust ingestion by children, characterized as "pica-type" behavior, could result in unacceptable risk to disease due to antimony, cadmium, mercury and lead intakes. This behavior, if observed, requires control to minimize adverse exposures.

Excessive and unacceptable sub-chronic and chronic exposures to cadmium and lead could occur from the **consumption of local garden produce** in the area. The growing and consumption of local garden produce should be controlled by discouraging and/or prohibiting such activity due to adverse health risk to children and adults. Alternatively, the growing of garden produce for consumption may be acceptable in non-contaminated soils, if the metals content of contaminated dusts and air particulate matter is controlled.

7.2.3 Consideration of Sub-chronic Noncarcinogenic Risk

Sub-chronic and short-term exposures are presented in Sections 5.2 and 6.2.2. Sub-chronic exposures and consequent intakes could increase health risks in the short term to levels well above those estimated for baseline chronic risks. **Ingestion of extreme amounts of soil and dust** during childhood (ages 2-6 years), characterized as "pica-type" behavior, could yield up to 10 times greater metal intakes than for the typical child. These extreme intakes due to soil/dust ingestion could amount to approximately 2 mg Pb/day, resulting in dangerous blood lead increases in young children. "Pica-type" behavior could present extreme risk to this highly susceptible sub-group of the population, and requires control if observed.

Consumption of local garden vegetables can yield extreme intakes of cadmium, lead and zinc. Up to 220 times as much lead can be ingested from the consumption of local garden vegetables grown in Smelterville and Kellogg versus that associated with the consumption of national market basket variety produce. Children and pregnant women, (as surrogates to the fetus) are most susceptible to the adverse effects associated with consequent lead intakes. Up to 62 times as much cadmium can be consumed in local garden produce versus market basket variety produce, thus presenting unacceptable chronic and sub-chronic risk to renal disease (see Section 6.2.1 and Table 6.6). Remedial alternatives addressing this activity were presented in Section 7.2.2.

Sub-chronic lead absorption among young children is the most significant health risk posed by this site. Multiple sources and environmental pathways are responsible for these absorptions. The principal baseline environmental media sources are contaminated soils and dusts. Significantly higher exposures can occur from consumption of local garden produce and "pica-type" behavior. The major exposure routes for baseline lead absorption are:

- **Ingestion of contaminated soils** in home yards and other residential environs (streets, parks, playgrounds, etc.),
- **Ingestion of contaminated house dusts** that are resultant from tracking of residential soils and deposition of airborne particulate,
- **Inhalation and ingestion of airborne particulate matter** derived from fugitive dust sources throughout the site.

An effective remedial strategy to reduce the potential for excess absorption on this site will have to consider an integrated approach for management of all primary and secondary exposure media.

Establishing cleanup targets for soil and for house dust requires the determination and selection of an appropriate blood lead threshold level. The recommended blood lead threshold level for children is in the range of 10-15 μg/dl, or possibly lower. In performing the baseline risk assessment a dose-response analysis was employed to evaluate the relationship between environmental media lead concentrations and blood lead levels. Sub-chronic exposures for children to lead contaminated media were presented and evaluated in Section 6.2.2. Projections of the percentage of children expected to exceed various blood lead levels are estimated using the integrated uptake/biokinetic dose-response model. The model was validated using historical lead health data for several surveys conducted in the area over the last 15 years (see Appendix C).

The model input parameters developed from the validation exercise for the baseline years, 1983 and 1989 (see Section 6.2.2.1 and Appendix C), were employed to develop a management matrix for soil/dust lead concentrations that is presented in Table 7.1. Table 7.1 was developed using a range of soil/dust lead dose coefficients observed since 1983 (smelter post-closure) for children ≤ 9 years of age. The lowest community mean dose coefficient was observed in 1988 at 11 mg/day and the highest at 14 mg/day for 1983. Other input parameters to the model included a 5.0 μg/day Pb intake for market basket food consumption and 5.0 μg/day intake associated with consumption of water from the Public Water Supply. Mean air lead uptake is assumed to be the same as current levels (0.3 μg/day) that was also used in the validation of the model. The soil/dust lead levels presented in Table 7.1 are represented as community mean values and <u>not</u> cleanup thresholds.

One difficulty in developing Table 7.1 was selection of the appropriate variance term for a post-remediation scenario blood lead response. As a result, Table 7.1 was developed by application of a range of empirically derived variance terms and the resultant blood lead distributions are presented in a corresponding range. The values used include a low geometric standard deviation (GSD) of 1.42 from the second U.S. National Health and Nutrition Examination Survey (NHANES II) study and a high of 1.71 observed for children ≤ 9 years of age in 1989. Additional considerations for predicting future blood lead response are provided in Attachment 1 to Appendix C.

The information provided in Table 7.1 can be used to evaluate remedial alternatives and predict community health effects outcomes. Table 7.1 expresses soil and dust lead exposures as community mean concentrations that must be achieved to result in the

Table 7.1
Mean Soil/Dust Lead Concentration (μg/gm) and Predicted Blood Lead Distributions for Site Children $\leq$ 9 Years of Age Using the Integrated Uptake/Biokinetic Dose-Response Model

	Blood Lead Concentrations Less Than or Equal to:			
Percent Children with:	10 μg/dl	12.5 μg/dl	15 μg/dl	25 μg/dl
50%	1,900-2,300			
60%	1,600-2,100			
70%	1,400-1,900	1,800-2,500		
80%	1,100-1,700	1,500-2,200	1,800-2,700	
85%	1,000-1,600	1,300-2,000	1,600-2,500	
90%	800-1,400	1,100-1,800	1,400-2,200	
95%	700-1,200	900-1,600	1,100-1,900	
97.5%	500-1,100	700-1,400	900-1,700	1,600-3,000
99%	400-900	600-1,200	700-1,500	1,300-2,600

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predicted blood lead distributions shown. For example, if mean soil and dust levels were both reduced to 500 $\mu g/gm$, less than 3% of children would be expected to exceed a 10 $\mu g/dl$ blood lead level. If both soil and dust levels averaged 1,000 $\mu g/gm$, as many as 15% of the children may exceed 10 $\mu g/dl$ blood lead. These community average levels can be achieved in a variety of ways. A 500 $\mu g/gm$ average can be accomplished by simultaneously reducing soils and dusts to 500 $\mu g/gm$. Alternatively, assuming that children's soil/dust exposures are proportioned 70% house dust and 30% yard soils (see Section 7 of JEG et al., 1989), mean soils could be reduced to 800 $\mu g/gm$ and dust controlled to 400 $\mu g/gm$.

Achieving these mean environmental levels in the community can also be accomplished in different ways. For soils, resultant community mean concentrations depend on:

- The cleanup level (i.e., all soils greater than the threshold value removed),
- The replacement soils concentration, and
- Soil lead levels remaining in non-remediated yards (i.e., those below the threshold).

For interior house dusts, resultant lead levels depend on:

- The level of cleanup achieved in soils,
- Level of control achieved in fugitive dusts sources, and
- Residual contaminant levels in the home.

Several combinations of these variables can achieve mean community environmental concentrations that result in acceptable blood lead levels. For example, a remedial strategy could include the application of a 1,000 $\mu g/gm$ residential soil lead cleanup level, a 500 $\mu g/gm$ house dust cleanup level, and a soil replacement and house dust maintenance concentration of 200 $\mu g/gm$. Replacing all contaminated soils > 1,000 $\mu g/gm$ with soils containing 200 $\mu g/gm$ results in a mean soil lead concentration of 235 μg/gm and a mean house dust lead concentration of 198 μg/gm (see Attachment 1 to Appendix C for determination of future mean soil and house dust lead concentrations). The weighted mean soil/dust lead concentration would be approximately 200 μg/gm. Table 7.1 shows that for children $\leq$ 9 years of age, a mean soil/dust lead concentration of 200 μg/gm would protect greater than 99% of the children at 10 µg Pb/dl blood. According to Table A6.1, approximately 85% of the residential soils in Smelterville, Kellogg, Wardner and Page would require replacement at a soil lead cleanup level of 1000 μg/gm and approximately the same percentage of home interiors requires remediation at a house dust cleanup level of 500 μg/gm.

However, consideration of separate lead cleanup or maintenance levels for soil and dust may not be effective. Information presented in Section 5.0 indicates that house dust metal concentrations are dependent on, and similar, to those for surface soils. For example, the ratio between mean house dust lead concentration to mean soil lead level was 1.0 in 1983 and 0.5 in 1988. Data show that 50-95% of the house dust is due to track-in from outdoors and consists primarily of soil and street dust (JEG et al., 1989). As a result, in order to assure greatest protection and long-term effectiveness, the lead cleanup or maintenance levels established for soil and house dust should be nearly equivalent.

Community mean soil and house dust lead concentrations following remediation are dependent on soil and house dust lead cleanup levels, the concentration of replacement soils, and appropriate management of contaminated dusts. Possible strategies for the mitigation of baseline lead exposures could include a combination of remedial activities. These would include, but not be limited to:

- Residential soils removal and replacement,
- Contaminated house dust removal and interiors maintenance,
- Fugitive dust source management and control, and

- Maintenance of a comprehensive community health/exposure intervention program.

Biokinetic modeling of this population indicates that use of the CDC advisory and EPA-OSWER directive of 500-1,000 μg/gm as a threshold cleanup level for soils and dusts would yield a blood lead response of less than 10 μg/dl for 97 to 100 percent of the childhood population. This prediction assumes that soil replacement values of less than 100 μg/gm lead could be maintained.

7.3 Recommendations

1. Reduce the sub-chronic risk of excess lead absorption to young children and pregnant women on the site. This can be achieved by reducing metals concentrations in particular environmental media and restricting access to, or stabilizing and preventing migration of, contaminants in other media.

    - The greatest risks to young children are associated with residential yard soils and house dusts. Substantial reductions in lead concentrations in these media will be required. Alternatives that reduce lead concentrations to appropriate levels by implementation of the current 500-1,000 μg/gm lead in soil and dust lead cleanup advisory should be addressed in the Feasibility Study. The biokinetic model developed for this site should be used to assess potential cleanup parameters for this effort on the basis of predicted post-remediation community blood lead distributions. This should include evaluation of the effects of the following on community blood lead distributions:

        - Concurrent soil and dust cleanup criteria (threshold levels requiring remediation),

        - Replacement soil criteria, and

        - Post-cleanup maintenance level goals.

    - Methods to effectively reduce dust lead loadings in homes should be investigated as a focused feasibility effort.

- Particular attention should be given to providing safe gardening locations for the production of home produce. Contaminated foodstuffs are an especially significant exposure route to pregnant women as well as young children. Garden soil lead criteria should be at least as stringent as residential yard requirements.

- Airborne contaminant transport of particulates and subsequent deposition should be reduced substantially. This can be achieved by stabilizing fugitive dust sources throughout the valley through appropriate cover or removal techniques. These alternatives should be investigated in focused feasibility efforts and implemented in conjunction with application of soil and dust remedies in the Populated Areas. Priority should be given to high lead concentration and high lead emission rate sources in proximity to the Populated Areas. Current metals deposition rates are excessive and should be reduced in order to:

    - Eliminate direct exposure to these highly concentrated dusts,

    - Reduce accumulation of these materials in homes and surface soils in the community,

    - Prevent excessive deposition on home-grown produce in local gardens, and

    - Protect applied soil remedies from recontamination.

- Contaminants from commercial properties, roadsides, and the railroad right-of-ways and fugitive dust sources should be stabilized, restricted from access or removed. These areas have extremely high metals levels and represent a direct contact hazard to young children, as well as being primary sources of fugitive dust to populated receptor areas. These alternatives should be investigated in focused feasibility studies and implemented in conjunction with soil and dust remedies.

2. Decrease carcinogenic risk to the general population by reducing airborne exposures to arsenic and cadmium and prohibiting the use of local groundwater as a drinking water source.

    - Airborne arsenic and cadmium concentrations can be reduced by stabilizing fugitive dust sources throughout the valley through appropriate cover or removal techniques. These alternatives should be investigated in conjunction with Recommendation 1. Particular attention should be given to high arsenic and cadmium concentration sources in proximity to the Populated Areas, especially those within the smelter complex and Central Impoundment Area (CIA).

- Groundwater consumption can be prevented by disallowing the use of this resource for potable water. Alternative supplies should be investigated as a Feasibility Study effort in the Non-populated Areas RI/FS.

3. Reduce risk to chronic and sub-chronic noncarcinogenic disease. The principal sources of excess noncarcinogenic risk are potential incremental activities involving consumption of garden produce, "pica-type" behavior in children, and potential use of local groundwater as a potable supply. These risks can be minimized by:

   - Implementing the recommendations regarding gardens suggested above,
   - Making health professionals aware of the special risks associated with pica in this area, and
   - Investigating substitute potable water supplies for the area.

   The latter should be undertaken as a feasibility study effort in the Non-populated Areas RI/FS. Other potential incremental exposures associated with activities in the Non-populated Areas should be addressed in the Non-populated Areas Baseline Risk Assessment.

4. Develop institutional controls to ensure maintenance of remedial goals. Because many of the recommendations include continued management of toxic materials on site and health awareness programs, remedial alternatives may include the following components in a comprehensive management plan:

   - In-situ stabilization techniques employing cover, barrier and access restriction strategies, and
   - Legal and institutional controls to ensure adequate maintenance and compliance, including monitoring for determination of long-term effectiveness of pollution management and control.

Institutional mechanisms to meet these needs should be investigated in concert with the remedial alternatives in feasibility study efforts. The continued need for some level of lead health and intervention programs should be reevaluated as remediation and source control efforts proceed.

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Appendix A

This Appendix contains additional tables and graphics referred to in the text of the report.

Table and Figure numbers correspond to the respective sections of this document. Dividers are found between sub-sections as follows:

Appendix A1 - List of DSRs and DERs
Appendix A2 - Material referenced in Section 2
Appendix A3 - Material referenced in Section 3
Appendix A4 - Material referenced in Section 4
Appendix A5 - Material referenced in Section 5
Appendix A6 - Material referenced in Section 6

Appendix A1

List of Data Summary Reports produced for the Populated Areas and Data Evaluation Reports produced for the Non-populated Areas

Table A1.1 (Page 1 of 3)
Bunker Hill Nonpopulated Areas RI/FS
Project Deliverables

Task No.	Description		Date
0	Determination of Contaminants of Concern		
	068-17011	Data Evaluation Report	11/23/88
1	Soils and Surficial Materials Investigation		
	098-1303	Data Evaluation Report--Soils and Surficial Materials Investigation	11/02/88
	157-13060	Revised Tech Memo: Hillside Soil Loss Evaluation Draft Responses	05/11/90
2	Surface Water Investigation		
	104-2920	Tech Memo: Aquatic Biology: Preliminary Data Interpretation #1	11/01/88
	142-29300	Data Evaluation Report--Aquatic Biology Addendum	05/09/90
	157-26030	Tech Memo--Revegetation Runoff	08/10/89
	169-27110	Data Evaluation Report--Surface Water	05/09/90

Table A1.1 (Page 2 of 3)
Bunker Hill Nonpopulated Areas RI/FS
Project Deliverables

Task No.	Description		Date
3	<u>Groundwater Investigation</u>		
	134-37070	Final Hydrogeologic Assessment	07/13/90
	180-37320	Model Protocol Report	05/09/90
	188-37100	DER--Final Hydrogeologic Assessment	06/21/90
4	<u>Air Investigation</u>		
	193-45030	Model Evaluation Study Report	08/03/90
5	<u>Vegetation & Terrestrial Biology Investigation</u>		
	160-54030	Data Evaluation Report--Veg. Growing Conditions Analysis	05/14/90
	168-59160	Data Evaluation Report--Terrestrial Biology Responses to EPA Comments	05/16/90
6	<u>Central Impoundment Area Investigation</u>		
	164-64110	Data Eval. Report--Final CIA Data Evaluation	05/21/90

Table A1.1 (Page 3 of 3)
Bunker Hill Nonpopulated Areas RI/FS
Project Deliverables

Task No.	Description		Date
7	Page Pond Investigation		
	167-74090	Data Evaluation Report--Page Pond	08/22/89
	167-74090	Addendum	08/14/90
8	Bunker Ltd. Shelter Complex Investigation		
	179-86510	Data Evaluation Report--Integrated Data Evaluation	09/17/90
9	Remedial Investigation Report		
	-92000	Draft RI Report Outline	03/23/89
12	Screen Remedial Technology		
	195-122150	Initial Feasibility Study Letter w/corrections	08/14/90
13	Focused Feasibility Study		
	186-134110	Onsite Waste Repository Selection Study Initial Evaluation of Alternatives	06/25/90

Table A1.2
Bunker Hill Populated Areas RI/FS
Data Summary Reports

Document Number	Description	Date
BHPA-RSL-F-R0-030690	Residential Soil and Litter Data Summary Report	March 1990
BHPA-SCDSR-D-R0-051890	1987 Soil Cores Data Summary Report	May 1990
BHPA-DSR87AF-F-R0-070990	Data Summary Report: 1987 Air Filters	July 1990
BHPA-FDS-F-R2-083190	Fugitive Dust Source Data Summary Report	August 1990
BHPA-PIIRI-F-R0-091790	Phase II Remedial Investigation Data Summary Report	September 1990

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Appendix A2

Material referenced in Section 2.

Table A2.1 1989 Fast-Track Sampling -- Laboratory Metals Data

Table A2.2 Organics and Mercury Data Summary Statistics for Residential Soils

Table A2.3 Fugitive Dust Source Metal Concentrations Summary

Table A2.4 Extreme TSP Days - Meteorological Particulate and Metals Summaries 1987-89

Table A2.5 Weekly Composited Filter Results and Dry Deposition Rates, Bunker Hill Project

Table A2.1
1989 Fast-Track Sampling--Laboratory Arsenic Data
(All data in mg/kg)

Wardner School	Core 1	Core 2	Core 3
Litter	7.7	13.1	13.3
0- to 1-inch of soil	7.7	7.7	9.5
Middle of fill	7.0	8.2	7.6
Bottom of fill	11.3	11.5	11
Top of cut	125	77	74.4
Wardner School Parking Lot			
0- to 1-inch of soil	11.6	10.8	10.3
Middle of fill	12.4	10.1	65.1
Bottom of fill	10.7	14.2	63.3
Top of cut	54.6	109.0	71.4
Teeters Field			
0- to 1-inch of soil	2.7	2.2	3.9
Middle of fill	4.6	3.3	2.2
Bottom of fill	2.4	4.4	5.8
Top of cut	56.0	105.0	142.0
Memorial Park Playground			
Litter	*	6.7	*
0- to 1-inch of soil	2.6	2.7	1.9
Middle of fill	3.0	4.1	1.7
Bottom of fill	7.5	3.0	4.1
Top of cut	50.1	17.7	28.1
Smelterville City Park			
Bark	16.8	20.7	3.3
Middle of fill	12.1	13.3	9.9
Bottom of fill	12.1	14.4	13.4
Top of cut	48.1	71.3	104.0
Little League Field			
0- to 1-inch of soil	4.2	3.3	4.6
Middle of fill	2.6	2.8	3.1
Bottom of fill	2.9	3.0	3.5
Top of cut	14.1	19.8	34.3

*No litter present.

Table A2.1 (Continued)
1989 Fast-Track Sampling--Laboratory Cadmium Data
(All data in mg/kg)

Wardner School	**Core 1**	**Core 2**	**Core 3**
Litter	1.2	1.6	1.0
0- to 1-inch of soil	1.8	1.1	.81
Middle of fill	1.4	.86	.81
Bottom of fill	.67	.36	.86
Top of cut	7.8	7.1	4.7
Wardner School Parking Lot			
0- to 1-inch of soil	1.6	1.9	1.5
Middle of fill	.79	.78	7.4
Bottom of fill	.64	.49	7.7
Top of cut	13.2	33.0	1.3
Teeters Field			
0- to 1-inch of soil	.55	.67	.52
Middle of fill	.69	.36	.36
Bottom of fill	.97	2.0	2.9
Top of cut	15.6	8.8	17.6
Memorial Park Playground			
Litter	*	1.9	*
0- to 1-inch of soil	.36	.38	.36
Middle of fill	.86	.58	.41
Bottom of fill	1.9	.64	.36
Top of cut	7.0	4.4	17.1
Smelterville City Park			
Bark	5.0	10.7	4.2
Middle of fill	.88	.81	1.1
Bottom of fill	1.9	2.6	3.0
Top of cut	30.6	99.6	23.4
Little League Field			
0- to 1-inch of soil	.84	.95	.63
Middle of fill	.39	.56	.41
Bottom of fill	.82	2.5	3.2
Top of cut	7.5	14	7.6

*No litter present.

Table A2.1 (Continued)
1989 Fast-Track Sampling--Laboratory Zinc Data
(All data in mg/kg)

Wardner School	Core 1	Core 2	Core 3
Litter	81	157	157
0- to 1-inch of soil	191	73	83
Middle of fill	75	66	80
Bottom of fill	103	78	102
Top of cut	1,360	1,090	839
Wardner School Parking Lot			
0- to 1-inch of soil	836	904	152
Middle of fill	78	56	1,620
Bottom of fill	66	57	1,740
Top of cut	2,850	6,310	482
Teeters Field			
0- to 1-inch of soil	56	74	66
Middle of fill	58	49	47
Bottom of fill	115	194	212
Top of cut	1,390	1,180	2,370
Memorial Park Playground			
Litter	*	167	*
0- to 1-inch of soil	67	56	49
Middle of fill	57	49	42
Bottom of fill	98	52	51
Top of cut	361	142	304
Smelterville City Park			
Bark	490	1,050	581
Middle of fill	53	50	66
Bottom of fill	149	126	127
Top of cut	2,280	4,340	1,120
Little League Field			
0- to 1-inch of soil	63.4	61	69
Middle of fill	52.5	33.4	34.7
Bottom of fill	64	225	109
Top of cut	753	1,260	642

* No litter present.

Table A2.1 (Continued)
1989 Fast-Track Sampling--Laboratory Lead Data
(All data in mg/kg)

Wardner School	Core 1	Core 2	Core 3
Litter	114	235	71
0- to 1-inch of soil	22	41	43
Middle of fill	57	42	32
Bottom of fill	143	56	225
Top of cut	25,100	5,330	3,500
Wardner School Parking Lot			
0- to 1-inch of soil	369	87	100
Middle of fill	74	18	3,170
Bottom of fill	260	71	4,230
Top of cut	2,850	4,850	603
Teeters Field			
0- to 1-inch of soil	22	77	43
Middle of fill	34	52	9
Bottom of fill	120	188	373
Top of cut	4,130	5,500	8,350
Memorial Park Playground			
Litter	*	173	*
0- to 1-inch of soil	25	26	15
Middle of fill	10	10	9
Bottom of fill	324	25	26
Top of cut	1,770	275	509
Smelterville City Park			
Bark	552	1,020	489
Middle of fill	403	19	32
Bottom of fill	128	148	169
Top of cut	3,510	4,910	4,410
Little League Field			
0- to 1-inch of soil	47.9	51.3	34
Middle of fill	23.0	7.6	9.4
Bottom of fill	19.2	15.1	39.8
Top of cut	921	2,040	1,760

*No litter present.

Table A2.2
Organics and Mercury Data Summary Statistics for Residential Soils
Smelterville
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
Di-n-Butylphthalate	755	765	670	--	'110	<1100	1	10
bis(2-Ethylhexyl)Phthalate	1053	795	934	--	<710	3100	1	10
Benzo(b)Fluoranthene	789	740	774	--	510	<1100	1	10
Mercury	5.31	4.05	3.58	--	0.47	12.6	10	10
4,4'-DDT	805	390	183	--	<5	4600	9	10
Chlordane	15922	3275	3689	--	184	81500	10	10
4,4'-DDD	131	53	49	--	<5	590	9	10
4'4'-DDE	222	25	43	--	4	1140	9	10
DDT, o, p'-	62	6	17	--	2	340	8	9
Heptachlor Epoxide	110	22.9	32	--	3	550	9	10
Toxaphene	3021	225	391	--	<88	25300	4	10
PCB-1260	43	44	37	--	<10	<90	1	10
PCB-1254	55	45	49	--	<20	<120	2	10

Note: All statistical calculations were conducted using detection limits as actual values.

Table A2.2 (Continued)
Organics and Mercury Data Summary Statistics for Residential Soils
Kellogg
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
Hexachlorocyclopentadiene	835	790	827	1200	<670	<1200	1	34
Dimethyl Phthalate	829	790	819	1200	530	<1200	1	34
Phenanthrene	693	785	514	1200	24	<1200	8	34
Di-n-Butylphthalate	637	770	463	1200	55	<1200	11	32
Fluoranthene	565	730	384	1200	40	<1200	12	33
Pyrene	614	770	411	1200	24	<1200	9	28
Butylbenzylphthalate	812	790	781	1200	150	<1200	2	34
Benzo(a)Anthracene	808	825	751	1200	110	<1200	2	28
bis(2-Ethylhexyl)Phthalate	759	770	670	1200	120	2300	11	31
Chrysene	779	790	717	1200	91	<1200	3	31
Benzo(b)Fluoranthene	889	825	863	1500	450	<1800	2	34
Benzo(a)Pyrene	781	800	694	1200	91	<1200	3	30
Indeno(1,2,3-cd)Pyrene	831	810	812	1200	300	<1200	1	29
Mercury	2.71	2.58	2.32	5.25	0.61	8.83	34	34
4,4'-DDT	1461	107	194	10000	<4	14000	32	34
Chlordane	5174	405	436	25000	<15	39300	23	34
4,4'-DDD	199	6	9	770	<0.7	5100	11	34
4'4'DDE	367	48	67	2200	<4	3200	31	34
DDT, o, p'-	202	12	20	1100	<0.7	3220	22	33
Heptachlor Epoxide	56	20	17	110	<1	190	2	7
Toxaphene	5392	100	253	73800	<69	85500	7	34
PCB-1260	69	47	46	210	<10	220	23	34
PCB-1254	164	108	106	480	17.8	<500	25	34
PCB-1242	44	20	26	200	<10	<480	1	33

Note: All statistical calculations were conducted using detection limits as actual values.

Table A2.2 (Continued)
Organics and Mercury Data Summary Statistics for Residential Soils
Wardner
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
Benzoic Acid	3130	3600	2600	--	480	<3900	1	6
Naphthalene	646	740	405	--	10	<840	1	7
Phenanthrene	431	300	281	--	35	<800	3	5
Di-n-Butylphthalate	651	745	538	--	96	<840	1	6
Fluoranthene	431	370	276	--	<47	<800	3	7
Pyrene	378	360	265	--	<53	<740	2	4
Benzo(a)Anthracene	674	750	593	--	130	<840	1	7
bis(2-Ethylhexyl)Phthalate	759	750	697	--	260	1300	2	7
Chrysene	596	740	516	--	160	<800	2	7
Benzo(b)Fluoranthene	711	740	701	--	470	<840	1	7
Benzo(k)Fluoranthene	569	710	463	--	93	<800	2	6
Benzo(a)Pyrene	587	740	487	--	110	<800	2	7
Mercury	1.00	0.96	1.02	--	0.30	4.25	7	7
4,4'-DDT	2329	16	53	--	4	14900	7	7
Chlordane	5180	21	148	--	<10	32000	6	7
4,4'-DDD	280	3	7	--	<1	1890	4	7
4,4'-DDE	584	7	24	--	2	3700	7	7
DDT, o, p'-	581	1	8	--	<1	4000	4	7
Heptachlor Epoxide	67	1	7	--	<1	290	4	7
Toxaphene	12609	100	272	--	<80	87600	1	7
PCB-1260	41	10	19	--	<10	<200	1	7
PCB-1254	59	16	31	--	<10	<200	4	7

Note: All statistical calculations were conducted using detection limits as actual values.

Table A2.2 (Continued)
Organics and Mercury Data Summary Statistics for Residential Soils
Page
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
bis(2-Ethylhexyl)Phthalate	12067	9750	10517	--	4000	20000	6	6

Note: All statistical calculations were conducted using detection limits as actual values.

Table A2.2 (Continued)
Organics and Mercury Data Summary Statistics for Residential Soils
Pinehurst
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
Benzyl Alcohol	580	750	448	--	88	<790	1	7
Dimethyl Phthalate	660	750	555	--	88	<800	1	7
Di-n-Butylphthalate	415	290	280	--	93	<800	4	7
Fluoranthene	587	750	463	--	130	<800	2	7
Pyrene	663	750	572	--	130	<800	1	6
Butylbenzylphthalate	714	750	705	--	470	<800	1	7
bis(2-Ethylhexyl)Phthalate	629	750	580	--	270	<790	2	7
Benzo(b)Fluoranthene	791	770	787	--	<690	1000	1	7
Mercury	1.53	1.39	1.31	--	0.38	3.28	7	7
4,4'-DDT	26	16	14	--	2	92	7	7
Chlordane	791	32	101	--	<10	3600	6	7
4,4'-DDD	6	2	3	--	<1	15	4	7
4,4'-DDE	30	5	10	--	3	99	7	7
DDT, o, p'-	8	2	3	--	<1	46	3	7
Heptachlor Epoxide	133	1	11	--	<1	550	3	7
Toxaphene	110	100	108	--	<86	150	1	7
PCB-1260	19	16	16	--	6.2	34	5	7
PCB-1254	19	10	16	--	<10	39	2	7

Note: All statistical calculations were conducted using detection limits as actual values.

Table A2.2 (Continued)
Organics and Mercury Data Summary Statistics for Residential Soils
Elizabeth Park
Concentration (µg/gm, dry wt.)

Element	Arithmetic Mean	Median	Geometric Mean	95 Percentile	Minimum	Maximum	Samples Over IDL	Total Samples
bis(2-Ethylhexyl)Phthalate	9086	9600	7946	--	3700	17000	6	7
Di-N-Octyl Phthalate	2790	3200	2041	--	130	<3400	1	7
4,4'-DDT	1551	1551	553	--	102	3000	2	2
Chlordane	1584	220	139	--	<0.21	10000	1	7
4,4'-DDE	395	395	148	--	29	760	2	2
DDT, o, p'-	611	611	159	--	21	1200	2	2
Toxaphene	7957	2100	1228	--	<2.1	45000	1	7
o, p'/pp DDT analogs	22	22	21	--	<20	<23	1	6

Note: All statistical calculations were conducted using detection limits as actual values.

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Table A2.3
Fugitive Dust Source Metal Concentrations Summary
Summary of Antimony Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	115	51.0	81.9	85.0	22.7	15.1	8
7	Undeveloped Area Near the Junior High School	6.40	3.90	5.05	4.30	1.0	26.0	4
11	Area Near Shoshone Apartments West Side	134	89.0	110	105	13.0	27.9	8
12	Water Treatment Plant	222	154	180	165	25.8	22.0	4
13	Concentrator West Parking Lot	9,840	3,030	5,720	4,140	2,590	30.3	4
16	CIA North Beaches	117	14.0	41.0	32.0	27.4	50.8	20
18	Bunker Creek Corridor West End	184	30.0	90.0	56.0	47.9	30.6	12
19	West Side Old Homesite Area	276	18.0	111	35.0	94.9	47.4	8
20	Old Gypsum Pond West Side	342	18.0	207	211	115	17.5	8
21	Gypsum Pond West End	107	2.20	26.4	6.00	33.2	30.3	12
25	Slag Pile West Side Area	329	20.0	82.7	39.0	96.1	15.3	12
33	Outdoor Theater Area East Central	250	14.0	74.3	36.0	81.8	17.9	8
34	Airport Area East End	76.0	28.0	42.2	39.0	11.2	28.7	24
38	Smelterville Corridor--East of Forest Products	160	37.0	64.4	56.0	26.8	33.2	16
39	River Channel East Flats	25.0	13.0	19.1	18.0	3.43	5.92	12
44	Page Pond Dikes	19.0	6.20	9.13	7.70	3.43	67.8	12
46	West Page Swamp East End	12.0	8.50	10.9	11.0	1.43	56.5	4
Zone B	Confidential	58.0	14.0	33.5	17.0	12.5	14.0	8

Table A2.3 (Continued)
Fugitive Dust Source Metal Concentrations Summary
Summary of Arsenic Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	328	153	250	226	54.8	15.1	8
7	Undeveloped Area Near the Junior High School	67.1	59.8	63.9	65.5	2.76	26.0	4
11	Area Near Shoshone Apartments West Side	358	130	235	241	74.5	27.9	8
12	Water Treatment Plant	1,660	1,000	1,180	1,010	279	22.0	4
13	Concentrator West Parking Lot	12,600	6,530	9,530	8,400	2,280	30.3	4
16	CIA North Beaches	1,500	154	692	560	389	50.8	20
18	Bunker Creek Corridor West End	780	223	450	395	158	30.6	12
19	West Side Old Homesite Area	1,190	103	449	182	353	47.4	8
20	Old Gypsum Pond West Side	767	156	557	665	200	17.5	8
21	Gypsum Pond West End	909	3.00	188	7.90	290	30.3	12
25	Slag Pile West Side Area	1,240	119	463	399	307	15.3	12
33	Outdoor Theater Area East Central	633	69.6	226	200	185	17.9	8
34	Airport Area East End	391	82.0	223	202	83.6	28.7	24
38	Smelterville Corridor--East of Forest Products	548	116	210	149	130	33.2	16
39	River Channel East Flats	649	131	302	276	146	5.92	12
44	Page Pond Dikes	409	78.0	202	151	93.0	67.8	12
46	West Page Swamp East End	120	85.0	107	106	13.4	56.5	4
Zone B	Confidential	337	98.0	184	157	86.9	14.0	8

Table A2.3 (Continued)
Fugitive Dust Source Metal Concentrations Summary
Summary of Cadmium Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	53.0	21.0	30.8	24.8	11.5	15.1	8
7	Undeveloped Area Near the Junior High School	20.0	13.8	17.1	16.6	2.27	26.0	4
11	Area Near Shoshone Apartments West Side	94.0	31.2	47.8	40.0	18.3	27.9	8
12	Water Treatment Plant	1,030	747	944	999	114	22.0	4
13	Concentrator West Parking Lot	16,100	1,060	11,100	12,500	5,950	30.3	4
16	CIA North Beaches	175	7.20	45.2	28.0	39.6	50.8	20
18	Bunker Creek Corridor West End	321	17.0	123	61.0	98.3	30.6	12
19	West Side Old Homesite Area	573	25.0	178	28.0	185	47.4	8
20	Old Gypsum Pond West Side	260	31.0	186	213	80.2	17.5	8
21	Gypsum Pond West End	87.0	4.40	24.4	6.80	29.4	30.3	11
25	Slag Pile West Side Area	838	12.0	192	62.0	238	15.3	12
33	Outdoor Theater Area East Central	156	9.40	56.7	61.0	51.1	17.9	8
34	Airport Area East End	133	18.4	49.0	44.0	31.3	28.7	24
38	Smelterville Corridor--East of Forest Products	121	35.0	69.3	66.0	18.8	33.2	16
39	River Channel East Flats	36.0	21.0	27.8	27.0	4.15	5.92	12
44	Page Pond Dikes	48.0	21.0	38.7	39.0	6.24	67.8	12
46	West Page Swamp East End	17.0	7.60	11.3	9.50	3.52	56.5	4
Zone B	Confidential	100	32.0	50.3	42.0	21.0	14.0	8

Table A2.3 (Continued)
Fugitive Dust Source Metal Concentrations Summary
Summary of Copper Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	663	277	450	440	134	15.1	8
7	Undeveloped Area Near the Junior High School	94.0	82.0	87.8	84.0	4.92	26.0	4
11	Area Near Shoshone Apartments West Side	613	435	538	539	51.8	27.9	8
12	Water Treatment Plant	4,420	3,080	3,770	3,780	477	22.0	4
13	Concentrator West Parking Lot	36,200	11,400	19,200	12,600	10,000	30.3	4
16	CIA North Beaches	1,640	65.0	313	131	388	50.8	20
18	Bunker Creek Corridor West End	2,090	213	829	580	518	30.6	12
19	West Side Old Homesite Area	3,930	156	1,330	212	1,300	47.4	8
20	Old Gypsum Pond West Side	1,210	253	871	897	319	17.5	8
21	Gypsum Pond West End	1,690	8.00	355	31.0	543	30.3	12
25	Slag Pile West Side Area	1,660	160	737	808	392	15.3	12
33	Outdoor Theater Area East Central	896	125	373	245	270	17.9	8
34	Airport Area East End	664	244	364	326	91.6	28.7	24
38	Smelterville Corridor--East of Forest Products	583	259	404	406	99.2	33.2	16
39	River Channel East Flats	209	155	185	184	14.5	5.92	12
44	Page Pond Dikes	161	80.0	114	94.0	31.1	67.8	12
46	West Page Swamp East End	2,790	2,310	2,470	2,360	188	56.5	4
Zone B	Confidential	412	217	315	320	60.3	14.0	8

Table A2.3 (Continued)
Fugitive Dust Source Metal Concentrations Summary
Summary of Lead Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	26,600	13,400	19,900	17,400	4,230	15.1	8
7	Undeveloped Area Near the Junior High School	2,500	1,160	1,810	1,670	482	26.0	4
11	Area Near Shoshone Apartments West Side	68,400	30,900	49,100	44,300	12,500	27.9	8
12	Water Treatment Plant	48,700	40,000	43,400	40,100	3,620	22.0	4
13	Concentrator West Parking Lot	252,000	212,000	232,000	223,000	15,700	30.3	4
16	CIA North Beaches	25,300	117	5,530	2,890	6,600	50.8	20
18	Bunker Creek Corridor West End	42,400	10,300	19,300	14,100	9,850	30.6	12
19	West Side Old Homesite Area	47,500	6,560	21,100	12,300	12,800	47.4	8
20	Old Gypsum Pond West Side	85,800	8,050	62,000	69,000	27,300	17.5	8
21	Gypsum Pond West End	10,900	78.0	2,160	309	3,390	30.3	12
25	Slag Pile West Side Area	18,200	1,370	10,700	11,200	4,990	15.3	12
33	Outdoor Theater Area East Central	15,900	2,950	9,190	14,900	3,830	17.9	8
34	Airport Area East End	28,200	11,100	15,500	15,000	3,510	28.7	24
38	Smelterville Corridor--East of Forest Products	32,700	11,600	19,800	17,700	6,070	33.2	16
39	River Channel East Flats	6,310	3,970	5,340	5,230	644	5.92	12
44	Page Pond Dikes	6,550	2,560	4,350	3,890	1,170	67.8	12
46	West Page Swamp East End	6,000	3,850	4,710	4,410	793	56.5	4
Zone B	Confidential	25,400	9,690	15,100	14,800	4,510	14.0	8

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Table A2.3 (Continued)
Fugitive Dust Source Metal Concentrations Summary
Summary of Zinc Statistics by Potential Source Area

Source Area Number	Description	High (mg/kg)	Low (mg/kg)	Average (mg/kg)	Median (mg/kg)	Std. Dev. (mg/kg)	Average Passing 200 Mesh (percent)	Number of Samples
6	Vacant Lot West Mineral Subdivision North Side	5,920	3,490	4,520	4,120	910	15.1	8
7	Undeveloped Area Near the Junior High School	1,140	518	781	660	231	26.0	4
11	Area Near Shoshone Apartments West Side	11,000	4,200	6,890	6,430	1,830	27.9	8
12	Water Treatment Plant	21,800	13,800	18,900	19,800	3,020	22.0	4
13	Concentrator West Parking Lot	41,900	16,400	35,100	40,700	10,800	30.3	4
16	CIA North Beaches	18,100	662	6,560	4,070	4,820	50.8	20
18	Bunker Creek Corridor West End	529,000	4,170	53,700	8,530	143,000	30.6	12
19	West Side Old Homesite Area	15,300	1,080	6,440	5,760	5,340	47.4	8
20	Old Gypsum Pond West Side	11,600	1,480	8,670	9,470	3,720	17.5	8
21	Gypsum Pond West End	5,690	99.0	1,290	566	1,630	30.3	12
25	Slag Pile West Side Area	59,700	5,090	21,800	16,400	16,100	15.3	12
33	Outdoor Theater Area East Central	5,990	1,330	3,460	2,810	1,700	17.9	8
34	Airport Area East End	13,100	2,860	6,050	4,340	2,960	28.7	24
38	Smelterville Corridor--East of Forest Products	12,000	4,510	8,120	7,650	2,130	33.2	16
39	River Channel East Flats	4,560	2,070	2,910	2,560	814	5.92	12
44	Page Pond Dikes	6,120	2,950	4,260	4,100	922	67.8	12
46	West Page Swamp East End	2,250	966	1,420	1,080	503	56.5	4
Zone B	Confidential	13,700	4,150	7,290	6,770	3,420	14.0	8

TABLE A2.4

Extreme TSP Days - Meteorological Particulate, and Metals Summaries 1987-89

APPENDIX A4.1 - EXTREME TSP DAYS WEATHER AND PARTICULATE SUMMARIES

1 - Pinehurst School
2 - Smelterville Sewage Lagoon
3 - Silver King School
4 - Mine Timber Company
5 - Drive-In Theatre/Truck Stop
6 - Kellogg Visitors Center
7 - Kellogg Middle School
8 - Mineral Subdivision
9 - Shoshone Apartments

15-Jul-87

Weather Summary

Hours	WS	WD	WDSTD
13	14.64	255.80	14.82
14	17.34	256.00	13.39
15	14.94	253.00	11.31
16	15.90	254.50	15.28
17	15.22	263.50	13.71
18	12.26	244.50	13.95
19	9.15	237.40	14.11
20	6.41	236.20	12.83

Daily Precip	0.00
3 Day Precip	0.00
[illegible] Day Precip	0.30
Daily Avg. WS	6.95
Daily Avg. WD	261.69
8-Hour Avg. WS	13.23
8-Hour Avg. WD	250.11

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	271	0.01	20	0.00	6	0.07	275	4.73	17443	0.04	166	0.10	361
-2	347	0.02	49	0.00	11	0.07	213	9.19	26471	0.87	2521	0.41	1191
-3	325	0.01	37	0.00	13	0.06	179	5.51	16965	0.25	762	0.15	472
-4	348	0.04	106	0.00	13	0.05	137	10.43	29984	1.13	3241	0.54	1562
-5	381	0.02	57	0.01	14	0.09	246	13.41	35193	1.80	4712	0.72	1903
-6	324	0.05	159	0.01	32	0.05	141	10.71	33070	0.58	1780	0.71	2176
-7	387	0.09	242	0.02	64	0.11	285	15.88	41034	0.73	1891	1.68	4333
-8	402	0.09	220	0.04	90	0.17	427	12.45	30974	1.81	4494	1.07	2674
-9	331	0.13	379	0.05	143	0.24	730	14.92	45074	1.86	5624	1.69	5106
9 Station Average	34[illegible].2	0.05	145	0.02	44	0.10	295	10.80	31205	1.01	2910	0.79	2272

17-Jul-87
Weather Summary

Hours	WS	WD	WDSTD
13	17.78	78.49	10.05
14	11.74	71.15	14.09
15	10.35	62.14	13.01
16	8.65	60.77	14.99
17	3.44	43.98	53.87
18	2.64	292.[illegible]	38.55
19	5.36	70.31	57.95
20	9.99	79.90	12.25

Daily Precip	0.04
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	8.25
Daily Avg. WD	56.85
8-Hour Avg. WS	8.74
8-Hour Avg. WD	94.93

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	40	0.01	155	0.00	38	0.12	2983	1.44	35912	0.19	4800	0.09	2151
-2	97	0.02	183	0.00	47	0.12	1226	5.92	61080	1.16	11991	0.50	5116
-3	73	0.09	1219	0.05	660	0.23	3218	4.40	60232	3.03	41461	0.30	4064
-4	193	0.05	272	0.03	173	0.14	728	17.84	92452	2.31	11961	1.20	6240
-5	61	0.01	186	0.00	74	0.09	1456	5.71	93612	0.52	8505	0.37	6051
-6	21	0.01	286	0.00	68	0.03	1261	0.59	27902	0.05	2380	0.03	1411
-7	29	0.01	300	0.00	52	0.25	8605	1.37	47210	0.03	1132	0.13	4635
-8	63	0.01	107	0.00	24	0.05	826	0.76	12142	0.04	639	0.06	952
-9	24	0.01	344	0.00	99	0.04	1835	0.83	34719	0.10	4130	0.09	3743
9 Station Average	66.8	0.02	343	0.01	165	0.12	1788	4.32	64667	0.83	12365	0.31	4603

28-Jul-87
Weather Summary

Hours	WS	WD	WDSTD
13	3.51	229.00	36.83
14	4.60	231.10	23.98
15	7.55	259.80	13.76
16	6.92	263.30	12.83
17	4.28	241.30	18.12
18	1.28	293.60	49.17
19	1.21	214.50	56.35
20	5.67	83.80	13.57

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.52
Daily Avg. WS	3.05
Daily Avg. WD	256.66
8-Hour Avg. WS	4.38
8-Hour Avg. WD	227.05

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	244	0.01	53	0.00	6	0.16	656	4.77	19565	0.27	1101	0.33	1340
-2	54	0.01	104	0.00	46	0.23	4314	1.33	24683	0.06	1141	0.04	763
-3	42	0.00	87	0.00	44	0.06	1338	1.15	27471	0.11	2609	0.04	946
-4	57	0.00	66	0.00	29	0.09	1628	1.41	24704	0.12	2032	0.06	992
-5	42	0.00	43	0.00	36	0.11	2616	1.06	25304	0.06	1406	0.04	951
-6	45	0.00	59	0.00	34	0.02	385	1.04	23158	0.23	5038	0.04	814
-7	46	0.01	120	0.00	33	0.15	3304	1.33	28955	0.12	2653	0.06	1237
-8	40	0.01	335	0.00	66	0.09	2364	1.09	27264	0.28	7075	0.04	1022
-9	57	0.01	249	0.00	62	0.11	1883	1.31	22936	0.38	6644	0.07	1169
-10	45	0.02		0.00		0.08		1.38		0.37		0.07	
9 Station Average	69.7	0.01	101	0.00	29	0.11	1632	1.61	23131	0.18	2592	0.08	1125

29-Jul-87
Weather Summary

Hours	WS	WD	WDSTD
13	8.34	246.30	10.64
14	7.18	254.70	14.25
15	7.32	242.30	16.26
16	8.16	250.30	10.80
17	4.21	222.90	10.47
18	2.50	261.10	54.60
19	1.72	285.90	43.65
20	2.14	72.38	34.10

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.02
Daily Avg. WS	3.96
Daily Avg. WD	256.62
8-Hour Avg. WS	5.20
8-Hour Avg. WD	229.49

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	240	0.01	60	0.00	6	0.10	430	3.32	13846	0.15	622	0.21	855
-2	74	0.01	124	0.00	26	0.17	2315	2.76	37343	0.49	6605	0.17	2250
-3	55	0.01	144	0.00	49	0.06	1123	1.72	31216	0.10	1839	0.07	1221
-4	73	0.01	144	0.00	22	0.04	520	1.69	23135	0.18	2435	0.08	1092
-5	56	0.01	109	0.00	27	0.14	2464	2.12	37889	0.12	2154	0.11	1993
-6	47	0.01	172	0.00	33	0.02	449	1.02	21687	0.08	1780	0.03	709
-7	47	0.01	186	0.00	54	0.14	2892	1.53	32520	0.19	4136	0.06	1282
-8	56	0.11	2048	0.01	213	0.16	2944	1.70	30426	1.44	25726	0.07	1247
-9	74	0.09	1221	0.02	289	0.19	2620	2.14	28896	2.54	34289	0.10	1387
-10	72	0.21		0.05		0.27		4.33		5.45		0.21	
9 Station Average	80.2	0.03	374	0.01	65	0.11	1424	2.00	24936	0.59	7332	0.10	1241

04-Aug-87
Weather Summary

Hours	WS	WD	WDSTD
13	6.11	281.20	28.45
14	9.88	271.50	17.89
15	15.14	254.20	17.56
16	14.51	258.20	15.29
17	13.12	254.70	13.13
18	11.59	259.10	11.16
19	9.69	252.00	13.81
20	5.15	271.30	12.69

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.05
Daily Avg. WS	5.47
Daily Avg. WD	262.72
8-Hour Avg. WS	10.65
8-Hour Avg. WD	262.78

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	130	0.01	40	0.00	12	0.07	568	3.16	24310	0.07	556	0.08	622
-2	257	0.01	41	0.00	9	0.12	467	3.17	12317	0.26	1005	0.15	602
-3	174	0.02	95	0.01	50	0.08	440	4.68	26892	0.46	2631	0.17	997
-4	181	0.03	148	0.00	23	0.06	351	7.45	41157	0.95	5250	0.45	2464
-5	198	0.02	85	0.00	23	0.14	719	9.22	46555	1.34	6786	0.56	2822
-6	146	0.03	189	0.01	74	0.04	305	4.89	33527	0.55	3785	0.30	2026
-7													
-8	231	0.00	0	0.07	302	0.49	2122	8.59	37176	6.41	27732	0.45	1936
-9	194	0.30	1563	0.08	410	0.47	2446	9.14	47104	7.33	37770	0.59	3053
-10	188	0.34		0.09		0.46		9.68		8.08		0.62	
9 Station Average	188.9	0.05	269	0.02	120	0.19	983	6.29	33284	2.17	11495	0.34	1820

28-Aug-87
Weather Summary

Hours	WS	WD	WDSTD
13	9.99	279.00	20.43
14	13.02	262.90	14.59
15	12.52	256.50	19.91
16	11.73	258.80	14.01
17	10.26	268.30	12.65
18	6.32	266.70	12.67
19	2.38	243.40	33.90
20	5.09	93.90	8.16

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	4.45
Daily Avg. WD	251.84
8-Hour Avg. WS	8.91
8-Hour Avg. WD	241.19

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	121	0.01	45	0.00	13	0.13	1060	2.68	22187	0.06	492	0.07	594
-2	131	0.01	57	0.00	16	0.17	1318	3.16	24088	0.14	1094	0.10	794
-3	137	0.01	89	0.00	34	0.08	552	4.28	31265	0.46	3379	0.19	1383
-4	183	0.02	117	0.00	23	0.07	381	8.19	44727	0.97	5318	0.55	3011
-5	137	0.01	79	0.00	19	0.12	879	5.09	37143	0.50	3642	0.28	2018
-6	110	0.01	119	0.01	61	0.05	481	3.05	27698	0.33	2996	0.10	933
-7	131	0.03	238	0.02	121	0.09	698	4.31	32923	0.80	6088	0.23	1777
-8	151	0.04	281	0.02	134	0.13	852	4.89	32364	1.23	8128	0.27	1777
-9	129	0.03	254	0.02	169	0.11	825	4.32	33511	1.00	7772	0.31	2367
-10	129	0.04		0.02		0.10		4.05		0.99		0.30	
9 Station Average	136.7	0.02	144	0.01	65	0.11	769	4.44	32493	0.61	4468	0.23	1709

02-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	18.79	267.10	12.37
14	15.37	253.30	17.70
15	15.06	254.10	12.72
16	16.02	247.50	15.42
17	10.42	223.80	32.02
18	6.68	240.60	[illegible]
19	3.72	178.30	63.87
20	7.44	82.50	10.25

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	6.90
Daily Avg. WD	230.55
8-Hour Avg. WS	11.71
8-Hour Avg. WD	[illegible]18.40

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	589	0.01	16	0.00	3	0.11	187	10.17	17265	0.13	228	0.22	375
-2	853	0.06	72	0.03	33	0.21	249	29.08	34089	3.91	4588	2.08	2444
-3	821	0.03	40	0.02	27	0.15	181	13.74	16734	0.97	1182	0.40	485
-4	915	0.10	113	0.02	25	0.19	210	34.44	37642	4.95	5414	2.32	2531
-5	811	0.08	97	0.02	21	0.17	206	26.39	32538	3.77	4651	1.62	1993
-6	722	0.13	181	0.06	81	0.17	238	21.57	29597	2.87	3980	1.31	1820
-7	904	0.41	459	0.15	167	0.36	402	56.00	61952	6.26	6926	5.93	6561
-8	691	0.28	399	0.11	160	0.41	598	20.27	29335	7.82	11323	0.79	1150
-9	690	0.38	553	0.16	225	0.62	894	20.70	29995	10.01	14511	1.31	1895
-10	744	0.63		0.24		0.76		34.74		15.46		2.04	
9 Station Average	777.3	0.17	213	0.06	81	0.27	342	25.80	33184	4.52	5820	1.78	2285

17-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	3.15	255.70	46.75
14	4.33	276.10	46.55
15	5.76	254.50	27.87
16	7.57	252.90	11.00
17	6.29	255.30	12.33
18	2.68	244.90	35.88
19	2.48	70.42	69.56
20	1.93	132.60	63.02

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	2.51
Daily Avg. WD	244.71
8-Hour Avg. WS	4.27
8-Hour Avg. WD	217.80

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	51	0.01	140	0.00	44	0.13	2588	1.61	31595	0.18	3572	0.07	1302
-2	229	0.18	767	0.01	61	0.21	937	13.34	58256	3.30	14406	1.68	7329
-3	36	0.01	176	0.00	119	0.06	1787	1.37	38026	0.17	4611	0.06	1546
-4	41	0.01	148	0.00	43	0.07	1798	1.95	47520	0.16	3960	0.10	2541
-5	35	0.01	193	0.00	48	0.12	3287	1.06	30175	0.30	8438	0.06	1587
-6	27	0.01	189	0.00	58	0.04	1363	0.76	28305	0.11	3931	0.03	1006
-7	26	0.00	191	0.00	73	0.08	3003	0.99	38013	0.09	3485	0.04	1406
-8	27	0.01	240	0.00	90	0.07	2597	0.64	23520	0.15	5643	0.02	869
-9	33	0.01	222	0.00	67	0.12	3646	0.77	23242	0.28	8433	0.03	978
-10	47	0.01		0.00		0.03		1.07		0.15		0.05	
9 Station Average	56.1	0.03	447	0.00	63	0.10	1792	2.50	44514	0.53	9371	0.23	4118

22-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	4.16	253.60	23.99
14	5.86	248.50	13.14
15	5.90	243.60	16.31
16	5.09	245.50	13.89
17	2.58	230.00	45.18
18	0.83	108.90	42.10
19	4.21	100.60	14.93
20	1.48	251.80	31.36

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	2.08
Daily Avg. WD	237.36
8-Hour Avg. WS	3.76
8-Hour Avg. WD	210.31

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	88	0.01	78	0.00	20	0.28	3178	2.29	26041	0.15	1752	0.10	1097
-2	44	0.01	145	0.00	48	0.16	3653	1.55	35303	0.14	3240	0.07	1647
-3	66	0.02	259	0.01	191	0.16	2465	2.14	32381	0.81	12252	0.10	1566
-4	75	0.01	124	0.00	44	0.09	1176	3.06	40785	0.44	5899	0.18	2385
-5	159	0.02	147	0.01	56	0.15	934	9.95	62557	1.49	9399	0.81	5068
-6	36	0.01	200	0.00	57	0.03	969	1.04	28910	0.12	3312	0.04	1186
-7	40	0.01	280	0.00	49	0.12	3041	1.30	32450	0.22	5468	0.06	1409
-8	49	0.01	136	0.00	71	0.08	1587	1.48	30220	0.17	3485	0.07	1367
-9	53	0.01	220	0.01	130	0.15	2751	1.92	36234	0.40	7511	0.13	2375
-10	44	0.01		0.01		0.05		1.61		0.34		0.11	
9 Station Average	67.8	0.01	163	0.00	70	0.14	2000	2.75	40537	0.44	6474	0.17	2539

23-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	3.68	262.30	18.69
14	5.48	255.00	11.81
15	5.59	245.30	16.54
16	5.48	250.90	13.20
17	3.19	231.20	37.79
18	1.54	100.10	43.84
19	3.54	98.50	29.01
20	1.11	251.40	22.41

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	2.03
Daily Avg. WD	239.91
8-Hour Avg. WS	3.70
8-Hour Avg. WD	211.84

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	104	0.01	59	0.00	19	0.23	2227	3.37	32407	0.17	1627	0.14	1330
-2	58	0.00	79	0.00	24	0.10	1659	1.12	19371	0.05	889	0.05	889
-3	46	0.01	167	0.01	182	0.14	3017	1.44	31345	0.32	6884	0.07	1582
-4	75	0.01	168	0.01	85	0.21	2827	4.78	63746	0.48	6455	0.30	4054
-5	108	0.02	214	0.00	38	0.16	1479	5.27	48765	0.81	7510	0.41	3763
-6	34	0.01	231	0.01	222	0.10	3041	1.35	39717	0.30	8840	0.05	1589
-7	39	0.00	125	0.00	87	0.08	2094	1.20	30747	0.18	4610	0.06	1518
-8	47	0.01	229	0.00	65	0.08	1664	1.21	25675	0.17	3619	0.06	1206
-9	194	0.03	135	0.08	412	0.26	1343	9.13	47086	2.68	13795	0.94	4856
-10	182	0.03		0.04		0.06		4.52		1.37		0.56	
9 Station Average	78.3	0.01	147	0.01	165	0.15	1932	3.21	40956	0.57	7318	0.23	2957

25-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	12.67	269.70	7.33
14	7.39	268.70	16.82
15	7.78	265.50	11.87
16	8.25	244.00	10.31
17	9.03	265.30	14.98
18	4.64	222.20	15.26
19	2.05	271.90	51.62
20	3.04	87.70	14.71

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	3.89
Daily Avg. WD	248.98
8-Hour Avg. WS	6.86
8-Hour Avg. WD	237.63

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	327	0.01	24	0.00	5	0.26	795	10.23	31272	0.12	376	0.25	749
-2	354	0.02	63	0.00	14	0.22	610	13.71	38730	0.89	2527	0.70	1966
-3	321	0.01	39	0.00	6	0.11	348	10.48	32655	0.25	778	0.28	865
-4	323	0.01	44	0.00	10	0.11	332	10.32	31951	0.41	1277	0.34	1061
-5	323	0.01	25	0.00	4	0.12	359	10.68	33057	0.20	625	0.27	836
-6	286	0.01	34	0.00	8	0.09	311	9.39	32826	0.15	536	0.23	812
-7	315	0.01	45	0.00	12	0.08	268	10.05	31916	0.25	806	0.27	869
-8	364	0.02	53	0.01	26	0.13	370	11.35	31168	0.58	1601	0.37	1029
-9	347	0.02	66	0.01	33	0.19	548	13.06	37631	1.10	3180	0.54	1552
-10	332	0.02		0.01		0.06		11.71		0.98		0.48	
9 Station Average	328.9	0.01	44	0.00	14	0.15	442	11.03	33534	0.44	1343	0.36	1098

26-Sep-87
Weather Summary

Hours	WS	WD	WDSTD
13	8.12	291.20	11.05
14	1.88	118.80	28.97
15	1.20	115.50	62.92
16	1.49	251.50	63.97
17	2.40	70.13	39.54
18	4.44	68.77	9.69
19	2.56	57.36	26.94
20	3.62	95.70	16.83

Daily Precip	0.09
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	3.64
Daily Avg. WD	289.21
8-Hour Avg. WS	3.21
8-Hour Avg. WD	133.62

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	155	0.00	24	0.00	10	0.21	1382	3.76	24279	0.04	261	0.07	479
-2	154	0.01	39	0.00	12	0.12	769	3.95	25638	0.13	825	0.09	570
-3	123	0.01	43	0.00	13	0.13	1081	3.29	26760	0.09	736	0.06	527
-4	129	0.00	37	0.00	11	0.09	705	3.24	25137	0.05	368	0.07	512
-5	115	0.00	30	0.00	12	0.13	1096	3.27	28454	0.04	382	0.07	569
-6	99	0.00	38	0.00	16	0.05	517	2.85	28807	0.03	302	0.06	573
-7		0.00		0.00		0.12		1.07		0.23		0.05	
-8	119	0.00	37	0.00	12	0.08	709	2.73	22928	0.04	370	0.06	507
-9	125	0.00	24	0.00	12	0.15	1235	3.14	25135	0.04	310	0.07	530
-10	121	0.00		0.00		0.04		3.01		0.03		0.06	
9 Station Average	127.4	0.00	34	0.00	14	0.12	949	3.03	23821	0.08	605	0.07	519

03-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	10.68	276.60	10.33
14	12.02	287.30	11.51
15	10.85	282.60	9.58
16	10.72	275.20	13.73
17	10.90	260.90	12.04
18	7.69	255.00	12.98
19	5.44	249.30	20.50
20	5.28	291.20	11.15

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	5.09
Daily Avg. WD	260.86
8-Hour Avg. WS	9.20
8-Hour Avg. WD	272.26

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	317	0.00	15	0.00	5	0.20	643	7.03	22190	0.06	204	0.17	527
-2	338	0.01	22	0.00	6	0.19	567	8.51	25176	0.21	625	0.23	690
-3	307	0.01	34	0.00	6	0.16	530	7.73	25187	0.38	1239	0.21	690
-4	285	0.01	30	0.00	6	0.05	172	7.82	27441	0.33	1144	0.26	899
-5	279	0.01	21	0.00	5	0.12	437	6.76	24245	0.27	969	0.23	813
-6	288	0.01	27	0.00	6	0.06	205	7.39	25668	0.18	629	0.20	690
-7	263	0.01	41	0.00	6	0.06	231	6.93	26343	0.15	585	0.21	80[illegible]
-8	303	0.03	93	0.01	28	0.13	436	8.84	29176	0.41	1341	0.49	1615
-9	268	0.04	142	0.01	44	0.19	723	9.27	34596	0.44	1656	0.68	2527
-10	274	0.03		0.01		0.07		8.81		0.37		0.58	
9 Station Average	294.2	0.01	46	0.00	12	0.13	444	7.81	26546	0.27	921	0.30	1009

07-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	3.31	228.80	20.37
14	4.66	236.60	17.16
15	3.88	231.80	25.90
16	5.20	276.30	21.36
17	2.62	263.70	22.37
18	1.51	274.20	59.52
19	2.47	96.80	40.68
20	2.30	129.70	56.35

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	1.99
Daily Avg. WD	239.83
8-Hour Avg. WS	3.24
8-Hour Avg. WD	217.24

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	168	0.01	52	0.00	10	0.20	1213	2.69	15986	1.71	10198	0.10	573
-2	122	0.01	73	0.00	16	0.23	1872	4.57	37449	0.32	2598	0.23	1916
-3	109	0.01	50	0.00	28	0.27	2489	3.72	34137	0.28	2532	0.12	1138
-4	158	0.01	85	0.00	13	0.09	567	3.73	23622	0.74	4708	0.21	1311
-5	139	0.01	73	0.00	11	0.10	725	2.84	20447	0.31	2243	0.14	1036
-6	94	0.00	51	0.00	15	0.09	946	1.87	19892	0.13	1358	0.07	731
-7	103	0.01	53	0.00	32	0.11	1038	2.91	28256	0.2[illegible]	2296	0.11	1116
-8	121	0.01	87	0.00	28	0.10	863	2.61	21602	0.28	2335	0.12	958
-9	171	0.05	272	0.01	81	0.18	1069	4.03	23586	0.84	4887	0.26	1548
-10	175	0.02		0.02		0.19		7.44		1.61		0.46	
9 Station Average	131.7	0.01	96	0.00	27	0.15	1162	3.22	24453	0.54	4088	0.15	1156

25-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	5.71	246.80	8.94
14	5.44	254.50	14.90
15	4.45	296.50	22.35
16	8.03	303.20	13.83
17	8.64	294.00	6.64
18	7.72	284.50	[illegible]
19	2.98	252.80	19.57
20	1.46	75.25	62.63

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	2.98
Daily Avg. WD	257.36
[illegible]	5.55
8-Hour Avg. WD	250.92

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	362	0.01	20	0.00	4	0.25	693	10.54	29119	0.07	190	0.24	654
-2	423	0.01	18	0.00	5	0.17	410	11.27	26653	0.08	184	0.27	632
-3	413	0.01	20	0.00	5	0.27	652	11.11	26894	0.18	435	0.26	631
-4	327	0.0[illegible]	23	0.00	4	0.07	207	10.03	30675	0.15	469	0.24	746
-5	402	0.02	38	0.00	5	0.19	481	14.08	35013	0.77	1918	0.63	1564
-6	312	0.01	17	0.00	5	0.07	226	8.43	27024	0.08	258	0.21	664
-7	327	0.01	23	0.00	5	0.13	395	8.77	26828	0.08	246	0.21	650
-8	370	0.01	30	0.00	8	0.17	469	10.28	27796	0.15	395	0.26	699
-9	342	0.01	31	0.00	4	0.21	601	10.53	30781	0.31	896	0.30	870
-10	323	0.01		0.00		0.10		10.23		0.23		0.28	
9 Station Average	364.2	0.01	25	0.00	5	0.17	468	10.56	28995	0.21	569	0.29	797

27-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	2.01	221.40	26.08
14	1.07	253.80	53.63
15	7.04	172.00	60.25
16	2.08	112.60	36.04
17	1.43	281.20	66.56
18	1.18	257.20	61.04
19	1.16	245.40	53.09
20	0.90	272.20	51.62

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	1.45
Daily Avg. WD	226.24
8-Hour Avg. WS	2.11
8-Hour Avg. WD	226.98

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	170	0.01	54	0.00	9	0.35	2043	2.93	17244	0.18	1056	0.12	734
-2	98	0.02	193	0.00	29	0.18	1799	3.39	34641	0.49	4978	0.22	2220
-3	112	0.02	177	0.01	79	0.19	1663	3.81	34031	0.78	6972	0.22	1983
-4	248	0.04	179	0.02	68	0.22	877	12.10	48779	2.49	10041	0.75	3033
-5	142	0.03	192	0.01	93	0.19	1373	6.05	42637	1.30	9123	0.43	3008
-6	47	0.01	127	0.00	70	0.06	1368	1.69	35957	0.26	5613	0.09	1935
-7	70	0.01	150	0.01	73	0.06	1137	2.10	29996	0.36	5104	0.12	1689
-8	81	0.01	175	0.01	65	0.09	1094	2.32	28599	0.36	4473	0.13	1585
-9	112	0.02	169	0.02	150	0.15	1320	3.80	33952	0.91	8155	0.23	2075
-10	105	0.02		0.02		0.08		3.37		0.72		0.21	
9 Station Average	120.0	0.02	156	0.01	68	0.17	1391	4.24	35369	0.79	6603	0.26	2142

28-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	2.44	268.80	32.61
14	2.32	243.10	13.08
15	1.19	174.20	61.28
16	1.05	110.00	38.08
17	1.82	173.20	65.56
18	0.96	259.90	36.97
19	0.83	251.50	71.75
20	1.21	228.50	75.54

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	1.34
Daily Avg. WD	218.94
8-Hour Avg. WS	1.48
8-Hour Avg. WD	213.65

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	192	0.01	51	0.00	8	0.34	1772	3.34	17370	0.21	1093	0.15	768
-2	71	0.01	178	0.00	48	0.16	2257	1.76	24727	0.37	5209	0.09	1282
-3	616	0.08	135	0.06	101	0.49	794	24.54	39843	8.59	13945	1.39	2263
-4	252	0.10	381	0.02	63	0.19	737	8.00	31764	1.97	7827	0.63	2506
-5	208	0.09	454	0.09	413	0.26	1244	6.19	29747	4.39	21123	0.40	1944
-6	51	0.01	148	0.01	148	0.09	1722	1.92	37622	0.63	12318	0.10	1965
-7	71	0.01	142	0.01	140	0.12	1659	2.14	30155	0.52	7280	0.11	1611
-8	96	0.02	158	0.01	97	0.09	916	2.01	20913	0.39	4083	0.11	1154
-9	114	0.04	315	0.02	142	0.14	1264	2.69	23640	0.79	6929	0.17	1492
-10	118	0.03		0.02		0.06		2.88		0.83		0.18	
9 Station Average	185.7	0.04	218	0.02	127	0.21	1120	5.84	31471	1.98	10690	0.35	1893

29-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	2.23	270.70	30.54
14	2.86	253.10	16.73
15	2.40	248.90	21.03
16	1.02	339.90	74.54
17	1.26	99.70	18.15
18	2.40	117.70	46.03
19	0.89	252.90	40.51
20	1.00	252.10	45.10

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	1.47
Daily Avg. WD	237.11
8-Hour Avg. WS	2.13
8-Hour Avg. WD	229.38

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1													
-2	64	0.00	72	0.00	54	0.17	2707	1.85	28950	0.20	3056	0.09	1383
-3	152	0.02	132	0.01	94	0.20	1317	4.68	30763	0.97	6374	0.29	1907
-4	158	0.02	154	0.02	133	0.16	997	5.24	33169	1.36	8629	0.37	2312
-5	111	0.02	145	0.02	193	0.17	1494	3.60	34203	0.98	8870	0.24	2121
-6	45	0.01	221	0.02	340	0.10	2116	1.50	33419	0.40	8861	0.08	1772
-7	74	0.02	206	0.03	368	0.13	1752	2.44	32918	0.64	8605	0.14	1881
-8	116	0.01	121	0.01	106	0.10	824	3.78	32579	0.59	5085	0.20	1722
-9	222	0.04	171	0.06	288	0.22	990	7.95	35818	2.58	11624	0.48	2158
-10	237	0.04		0.06		0.59		8.08		2.74		0.47	
9 Station Average	117.8	0.02	151	0.02	190	0.15	1313	3.90	33160	0.96	8193	0.23	1992

30-Oct-87
Weather Summary

Hours	WS	WD	WDSTD
13	3.02	257.00	16.24
14	2.56	281.40	15.13
15	1.97	290.80	26.06
16	1.13	242.60	43.42
17	1.33	212.20	57.58
18	0.75	13.30	70.67
19	0.60	256.40	54.44
20	1.14	254.00	51.00

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	1.32
Daily Avg. WD	247.88
8-Hour Avg. WS	1.56
8-Hour Avg. WD	225.96

Particulate Summary

Sampler	TSP ug/m3	As ug/m3	As ppm	Cd ug/m3	Cd ppm	Cu ug/m3	Cu ppm	Fe ug/m3	Fe ppm	Pb ug/m3	Pb ppm	Mn ug/m3	Mn ppm
-1	161	0.01	44	0.00	15	0.44	2711	3.39	21060	0.22	1344	0.15	912
-2	83	0.01	73	0.00	51	0.14	1740	2.83	34106	0.25	3028	0.14	1656
-3	121	0.01	97	0.01	75	0.21	1734	4.04	33395	0.71	5859	0.25	2039
-4	166	0.03	189	0.01	64	0.15	929	6.76	40703	1.23	7420	0.47	2853
-5	142	0.03	223	0.01	83	0.21	1472	6.35	44727	1.27	8978	0.48	3405
-6	54	0.00	71	0.00	69	0.09	1659	1.61	29823	0.17	3110	0.07	1254
-7	64	0.01	83	0.00	76	0.10	1496	1.99	31027	0.23	3638	0.10	1536
-8	96	0.03	293	0.02	202	0.11	1182	3.00	31253	0.73	7608	0.17	1768
-9	93	0.03	365	0.06	691	0.16	1723	3.28	35268	1.18	12664	0.21	2298
-10	90	0.03		0.07		0.10		3.31		1.18		0.21	
9 Station Average	108.9	0.02	162	0.01	133	0.18	1646	3.69	33925	0.67	6114	0.23	2079

8-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	12.65	41.51	19.18
14	15.71	47.76	17.70
15	14.80	43.59	14.24
16	16.58	51.42	13.84
17	16.76	46.98	16.19
18	12.33	38.25	12.11
19	13.73	62.07	10.95
20	12.97	67.94	10.63

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	1.00
Daily Avg. WS	7.90
Daily Avg. WD	60.45
8-Hour Avg. WS	14.44
8-Hr. Avg. WD	49.94

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	632.4	41.9	0.005	113	0.006	151	0.06	1534	0.09	2123	0.0002	5
2	512.6	26.7	0.006	219	0.008	292	0.02	708	0.14	5230	0.0003	9
4	712.1	344.6	0.032	92	0.023	67	0.13	377	3.55	10310	0.0028	8
5	700.4	52.1	0.007	137	0.006	110	0.07	1264	0.58	11218	0.0010	19
5A	510.1	22.0	0.006	267	0.008	356	0.06	2582	0.26	12021	0.0006	28
7	603.4	23.2	0.005	215	0.007	286	0.10	4152	0.07	2992	0.0005	21
7A	500.4	14.2	0.006	422	0.008	563	0.02	1336	0.03	1913	0.0002	14
8	700.3	28.8	0.004	149	0.006	199	0.04	1306	0.14	4836	0.0003	12
9	540.2	78.7	0.009	111	0.007	94	0.06	727	0.95	12065	0.0009	11
Average (Hi-Vol)		85.1	0.010	148	0.009	171	0.07	1438	0.79	6968	0.0008	12
Average (PM-10)		18.1	0.006	345	0.008	459	0.04	1959	0.15	6967	0.0004	21

13-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	5.47	227.70	18.55
14	5.61	223.00	13.92
15	5.10	216.90	18.83
16	5.77	224.20	11.37
17	4.03	207.10	9.94
18	3.28	70.02	50.68
19	5.10	78.66	10.96
20	1.75	189.60	72.94

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	2.39
Daily Avg. WD	235.53
8-Hour Avg. WS	4.51
8-Hr. Avg. WD	179.65

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	599.8	80.3	0.005	62	0.007	83	0.18	2264	0.07	903	0.0002	2
2	515.1	68.5	0.006	85	0.008	113	0.09	1383	0.07	1077	0.0002	3
4	720.0	85.5	0.007	80	0.006	65	0.07	762	0.39	4518	0.0003	3
5	721.5	62.3	0.004	60	0.006	89	0.04	639	0.12	1908	0.0003	4
5A	534.1	46.3	0.006	121	0.007	162	0.01	275	0.10	2172	0.0003	6
7	585.2	60.7	0.005	84	0.007	113	0.23	3771	0.08	1337	0.0002	4
7A	511.1	47.1	0.006	125	0.008	166	0.02	494	0.06	1357	0.0003	5
8	709.0	160.8	0.044	275	0.006	36	0.08	499	0.70	4342	0.0009	6
9	549.0	93.1	0.014	155	0.011	119	0.13	1353	0.57	6107	0.0009	10
Average (Hi-Vol)		87.3	0.012	114	0.007	88	0.12	1524	0.29	2885	0.0004	5
Average (PM-10)		46.7	0.006	123	0.008	164	0.02	385	0.08	1765	0.0003	6

15-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	5.64	275.90	31.92
14	12.11	232.40	20.93
15	9.42	209.70	16.73
16	10.50	223.70	14.92
17	5.90	228.80	13.62
18	1.77	248.50	51.53
19	2.27	78.54	54.09
20	2.95	75.90	46.70

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	3.12
Daily Avg. WD	227.98
8-Hour Avg. WS	6.32
8-Hr. Avg. WD	196.68

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	630.2	308.7	0.004	14	0.004	12	0.13	428	0.07	214	0.0002	1
2	501.6	349.1	0.005	13	0.004	11	0.11	313	0.06	158	0.0002	1
4	723.9	276.9	0.006	22	0.005	19	0.07	246	0.19	684	0.0006	2
5	726.9	360.4	0.006	17	0.004	10	0.05	135	0.16	439	0.0003	1
5A	530.0	163.6	0.004	24	0.004	27	0.06	337	0.13	806	0.0003	2
7	594.9	278.1	0.023	82	0.007	27	0.25	888	0.51	1843	0.0012	4
7A	521.9	126.5	0.013	106	0.005	42	0.05	426	0.19	1488	0.0005	4
8	686.4	335.0	0.032	96	0.019	57	0.08	247	1.45	4331	0.0016	5
9	540.1	397.7	0.053	133	0.044	110	0.24	596	2.50	6286	0.0039	10
Average (Hi-Vol)		329.4	0.018	54	0.012	35	0.13	408	0.70	1994	0.0011	3
Average (PM-10)		145.0	0.009	65	0.005	34	0.05	381	0.16	1147	0.0004	3

[redacted]

16-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	4.04	236.00	27.89
14	8.36	262.10	16.25
15	9.24	260.60	14.84
16	8.26	258.80	12.17
17	4.09	227.10	16.81
18	1.21	236.20	23.01
19	1.54	9.11	65.23
20	3.98	69.58	17.00

Daily Precip	0.00
3 Day Precip	0.00
6 Day Precip	0.00
Daily Avg. WS	3.42
Daily Avg. WD	232.51
8-Hour Avg. WS	5.09
8-Hr. Avg. WD	194.94

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	105.8	175.3	0.026	146	0.020	113	0.27	1563	0.18	1008	0.0011	6
2	539.1	91.2	0.004	41	0.004	41	0.08	877	0.05	543	0.0003	3
4	719.6	80.1	0.003	42	0.004	56	0.06	744	0.09	1182	0.0003	4
5	724.0	286.0	0.014	49	0.006	22	0.05	169	1.22	4250	0.0018	6
5A	530.1	144.4	0.008	54	0.006	41	0.03	205	0.74	5110	0.0009	6
7	606.0	76.4	0.004	50	0.004	52	0.25	3325	0.05	708	0.0003	4
7A	522.0	46.1	0.004	79	0.005	104	0.03	549	0.03	724	0.0002	5
8	686.7	115.2	0.007	59	0.004	32	0.04	358	0.32	2744	0.0004	4
9	541.2	108.3	0.008	72	0.007	65	0.14	1295	0.28	2627	0.0008	7
Average (Hi-Vol)		133.2	0.009	65	0.007	54	0.13	1190	0.31	1866	0.0007	5
Average (PM-10)		95.2	0.006	66	0.005	72	0.03	377	0.39	2917	0.0006	6

25-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	2.69	215.00	24.69
14	2.59	211.60	25.59
15	1.02	228.60	31.23
16	0.71	97.50	43.05
17	4.42	61.97	17.18
18	3.45	69.45	50.90
19	1.24	237.10	19.37
20	1.63	221.50	37.13

Daily Precip	0.00
3 Day Precip	0.01
6 Day Precip	6.87
Daily Avg. WS	2.28
Daily Avg. WD	226.45
8-Hour Avg. WS	2.22
8-Hr. Avg. WD	167.84

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	569.2	160.0	0.007	42	0.004	22	0.07	451	0.08	480	0.0002	1
2	527.9	218.8	0.005	25	0.004	17	0.14	644	0.07	299	0.0002	1
4	722.1	177.3	0.006	35	0.003	16	0.20	1140	0.25	1383	0.0003	2
5	728.3	236.1	0.006	24	0.004	15	0.08	360	0.36	1512	0.0004	2
5A	507.5	62.9	0.005	85	0.004	63	0.04	630	0.19	3019	0.0002	3
7	613.7	199.3	0.010	52	0.004	22	0.31	1545	0.29	1463	0.0004	2
7A	498.2	113.0	0.009	82	0.004	36	0.07	595	0.15	1337	0.0002	2
8	693.5	224.8	0.013	57	0.007	30	0.08	343	0.69	3067	0.0008	3
9	533.6	261.4	0.017	66	0.009	36	0.18	678	0.60	2280	0.0007	3
10	534.8	261.2	0.013	51	0.007	29	0.12	472	0.49	1868	0.0007	3
Average (Hi-Vol)		217.4	0.010	44	0.005	23	0.15	704	0.35	1544	0.0005	2
Average (PM-10)		88.0	0.007	83	0.004	49	0.05	612	0.17	2178	0.0002	3

26-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	6.65	225.50	10.71
14	5.52	230.20	16.13
15	5.47	234.40	11.57
16	5.90	225.90	13.13
17	3.55	233.80	25.33
18	1.97	262.90	55.80
19	3.78	75.99	37.57
20	1.94	244.40	78.84

Daily Precip	0.00
3 Day Precip	0.01
6 Day Precip	1.02
Daily Avg. WS	3.79
Daily Avg. WD	214.27
8-Hour Avg. WS	4.35
8-Hr. Avg. WD	216.64

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	650.0	274.4	0.004	15	0.003	11	0.12	426	0.07	239	0.0005	2
2	536.4	254.7	0.004	15	0.004	15	0.08	330	0.04	159	0.0003	1
4	721.7	262.1	0.005	17	0.003	11	0.11	402	0.13	500	0.0006	2
5	736.8	214.0	0.004	16	0.003	13	0.04	183	0.06	297	0.0003	2
5A	505.5	199.2	0.004	22	0.004	20	0.03	129	0.05	261	0.0004	2
7	617.5	218.0	0.005	22	0.003	15	0.42	1939	0.07	311	0.0008	4
7A	518.3	125.2	0.003	23	0.004	31	0.04	304	0.03	230	0.0009	8
8	696.3	367.5	0.017	45	0.007	20	0.11	293	1.38	3744	0.0014	4
9	536.7	278.0	0.011	39	0.005	19	0.19	670	0.24	871	0.0006	2
10	561.3	273.0	0.012	42	0.004	16	0.09	339	0.18	659	0.0007	2
Average (Hi-Vol)		267.7	0.007	27	0.004	15	0.14	573	0.27	847	0.0006	2
Average (PM-10)		162.2	0.004	22	0.004	25	0.03	216	0.04	245	0.0007	5

27-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	4.39	203.80	19.83
14	4.20	212.80	24.98
15	3.39	224.20	21.76
16	4.87	232.70	17.57
17	4.08	211.00	24.54
18	1.89	0.71	59.34
19	4.41	78.23	16.11
20	2.12	74.61	75.24

Daily Precip	0.01
3 Day Precip	0.01
6 Day Precip	0.02
Daily Avg. WS	2.17
Daily Avg. WD	222.72
8-Hour Avg. WS	3.67
8-Hr. Avg. WD	154.76

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	575.6	93.8	0.004	44	0.003	37	0.10	1063	0.07	748	0.0002	2
2	528.2	73.8	0.003	46	0.004	51	0.09	1245	0.05	670	0.0002	3
4	736.2	68.4	0.004	56	0.003	40	0.11	1569	0.14	2046	0.0003	4
5	745.4	70.8	0.005	66	0.003	44	0.09	1225	0.26	3636	0.0003	5
5A	506.1	47.4	0.005	104	0.004	83	0.05	1071	0.12	2634	0.0002	4
7	618.0	66.0	0.007	103	0.004	66	0.43	6544	0.22	3358	0.0006	9
7A	526.5	41.9	0.003	72	0.004	91	0.06	1463	0.05	1277	0.0003	6
8	694.8	153.3	0.012	80	0.006	40	0.09	601	0.97	6336	0.0010	7
9	539.0	109.6	0.019	169	0.009	86	0.13	1144	0.70	6379	0.0011	10
10	548.4	108.3	0.018	162	0.007	66	0.13	1198	0.72	6620	0.0011	10
Average (Hi-Vol)		93.0	0.009	91	0.005	54	0.15	1824	0.39	3724	0.0006	6
Average (PM-10)		44.7	0.004	88	0.004	87	0.06	1267	0.09	1956	0.0002	5

28-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	3.17	196.00	26.63
14	2.57	192.70	28.02
15	3.77	193.70	17.77
16	3.64	202.90	10.92
17	3.71	129.70	56.79
18	5.66	87.20	13.61
19	2.82	95.10	42.01
20	1.50	226.50	33.94

Daily Precip	0.01
3 Day Precip	0.02
6 Day Precip	0.03
Daily Avg. WS	1.89
Daily Avg. WD	205.95
8-Hour Avg. WS	3.36
8-Hr. Avg. WD	165.48

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	644.2	90.7	0.009	99	0.003	34	0.14	1498	0.09	955	0.0002	2
2	533.2	40.7	0.008	189	0.004	92	0.09	2242	0.05	1110	0.0002	5
4	730.6	74.8	0.009	126	0.003	37	0.11	1520	0.29	3914	0.0004	5
5	755.1	58.7	0.007	124	0.003	45	0.07	1115	0.15	2618	0.0002	4
5A	505.3	42.6	0.008	177	0.004	93	0.04	879	0.12	2775	0.0003	7
7	608.6	69.6	0.004	64	0.006	92	0.40	5784	0.09	1261	0.0004	6
7A	551.3	33.6	0.008	232	0.004	108	0.06	1914	0.09	2733	0.0002	6
8	694.0	180.7	0.020	111	0.014	77	0.12	673	1.39	7703	0.0020	11
9	536.8	105.0	0.018	168	0.012	113	0.18	1740	0.70	6632	0.0010	9
10	538.9	98.6	0.013	134	0.014	137	0.10	1045	0.70	7058	0.0013	13
Average (Hi-Vol)		89.9	0.011	127	0.007	78	0.15	1952	0.43	3906	0.0007	7
Average (PM-10)		38.1	0.008	204	0.004	100	0.05	1396	0.11	2754	0.0002	6

29-SEP-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	3.79	231.80	18.16
14	4.34	239.30	23.27
15	5.25	232.30	13.07
16	3.90	211.30	9.97
17	1.71	82.10	53.64
18	5.15	79.15	16.82
19	2.17	90.80	35.02
20	1.34	234.90	29.89

Daily Precip	0.00
3 Day Precip	0.02
6 Day Precip	0.03
Daily Avg. WS	2.13
Daily Avg. WD	209.38
8-Hour Avg. WS	3.46
8-Hr. Avg. WD	175.21

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	642.7	97.3	0.005	56	0.003	32	0.08	801	0.10	1014	0.0002	2
2	545.4	55.4	0.003	63	0.004	66	0.08	1480	0.07	1351	0.0002	3
4	721.9	59.7	0.004	70	0.003	46	0.15	2483	0.15	2552	0.0003	4
5	740.4	70.0	0.005	66	0.003	42	0.06	852	0.30	4223	0.0003	4
5A	508.6	51.9	0.006	125	0.004	76	0.05	874	0.18	3509	0.0005	10
7	605.7	58.5	0.005	93	0.003	59	0.43	7423	0.11	1891	0.0003	6
7A	521.6	46.2	0.004	91	0.004	83	0.08	1798	0.08	1740	0.0002	5
8	600.4	254.2	0.024	94	0.013	50	0.17	688	2.05	8059	0.0018	7
9	523.2	132.5	0.016	121	0.010	74	0.21	1602	0.92	6911	0.0009	7
10	540.3	124.2	0.015	124	0.015	124	0.13	1014	0.98	7915	0.0014	11
Average (Hi-Vol)		106.5	0.010	86	0.007	62	0.16	2043	0.58	4239	0.0007	6
Average (PM-10)		49.1	0.005	108	0.004	79	0.06	1336	0.13	2624	0.0004	7

10-OCT-89
Weather Summary

Hours	Wind Speed (mph)	Wind Direction (deg)	WDSTD (deg)
13	15.10	227.50	12.53
14	17.63	234.50	12.28
15	13.23	228.90	16.04
16	11.51	230.60	10.33
17	15.59	242.70	13.36
18	10.29	266.80	18.81
19	6.86	255.70	17.86
20	8.41	250.50	16.70

Daily Precip	2.00
3 Day Precip	2.00
6 Day Precip	2.00
Daily Avg. WS	6.15
Daily Avg. WD	232.16
8-Hour Avg. WS	12.33
8-Hr. Avg. WD	242.15

Particulate Summary

Sampler No.	Total Flow (m3)	TSP (ug/m3)	As (ug/m3)	As (ppm)	Cd (ug/m3)	Cd (ppm)	Cu (ug/m3)	Cu (ppm)	Pb (ug/m3)	Pb (ppm)	Hg (ug/m3)	Hg (ppm)
1	647.5	244.5	0.010	42	0.006	25	0.10	392	0.05	222	0.0002	1
2	556.2	263.8	0.008	30	0.007	27	0.12	444	0.23	859	0.0007	3
4	730.8	254.7	0.011	45	0.006	23	0.07	267	0.35	1380	0.0005	2
5	720.5	682.7	0.016	23	0.012	17	0.07	101	1.31	1917	0.0019	3
5A	528.9	321.3	0.020	61	0.008	24	0.13	417	0.79	2460	0.0014	4
7	605.2	242.1	0.028	117	0.008	33	0.71	2941	0.52	2136	0.0008	3
7A	535.4	98.8	0.021	208	0.007	76	0.06	616	0.44	4422	0.0008	8
8	693.7	390.3	0.078	201	0.042	108	0.17	425	3.33	8532	0.0032	8
9	521.0	356.1	0.059	165	0.062	175	0.32	889	2.88	8086	0.0067	19
10	573.1	340.6	0.060	177	0.094	276	0.23	666	4.01	11782	0.0068	20
Average (Hi-Vol)		346.8	0.034	100	0.030	85	0.22	766	1.59	4364	0.0026	7
Average (PM-10)		210.1	0.020	135	0.008	50	0.10	517	0.61	3441	0.0011	6

Table A2.5

WEEKLY COMPOSITED FILTER RESULTS
BUNKER HILL PROJECT - SMELTERVILLE, IDAHO
NOVEMBER 8, 1987 - NOVEMBER 7, 1988

Week No.	Composite Group No.	Week Ending Date	Average TSP Conc. (ug/scm)	Average Cadmium Conc. (ng/scm)	Average Lead Conc. (ng/scm)
1	7	871109	99.1	3.89	464.17
2	8	871116	53.5	3.85	261.22
3	1	871123	72.6	16.62	410.74
4	9	871130	53.0	1.77	127.43
5	10	871207	41.0	1.38	128.52
6	11	871214	49.0	2.64	166.61
7	12	871221	43.4	0.90	60.49
8	13	871228	71.2	1.71	92.50
9	14	880104	62.1	3.22	135.71
10	15	880111	40.6	0.59	43.94
11	16	880118	51.6	0.74	78.43
12	2	880125	83.1	2.07	129.51
13	17	880201	66.4	5.35	161.08
14	18	880208	50.3	1.42	69.37
15	19	880215	50.3	0.68	74.47
16	3	880222	117.8	4.84	538.08
17	4	880229	155.4	6.02	540.79
18	20	880307	52.2	1.43	108.61
19	21	880314	45.1	1.04	104.90
20	5	880321	82.5	2.06	297.35
21	22	880328	45.9	0.78	74.19
22	23	880404	36.0	0.73	74.61
23	24	880411	42.1	1.35	121.71
24	6	880418	93.9	5.61	654.39
25	25	880425	26.8	1.34	130.05
26	26	880502	30.6	1.34	143.92
27	27	880509	28.3	0.99	88.28
28	28	880516	66.1	2.31	368.75
29	29	880523	39.5	0.78	117.02
30	30	880530	28.2	0.58	56.98
31	31	880606	29.3	0.58	76.07
32	32	880613	31.7	0.46	99.11
33	33	880620	69.1	1.36	272.63
34	34	880627	62.5	1.14	273.46
35	35	880704	31.9	0.40	82.58
36	36	880711	48.6	0.51	114.01
37	37	880718	27.5	0.46	116.30
38	38	880725	73.6	1.74	478.23
39	39	880801	118.9	3.34	743.11
40	40	880808	78.5	3.28	549.00
41	41	880815	76.2	1.56	461.17
42	42	880822	144.9	5.53	1345.70
43	43	880829	164.3	4.97	1211.97
44	44	880905	161.0	6.51	1309.34
45	45	880912	225.2	4.38	1245.34
46	46	880919	89.1	2.83	409.83
47	47	880926	46.6	1.98	230.05
48	48	881003	76.9	3.16	417.90
49	49	881010	74.8	1.89	497.79
50	50	881017	95.6	3.00	379.26
51	51	881024	65.4	1.81	124.53
53	52	881031	82.5	2.61	194.21
53	53	881107	33.7	1.08	92.67
	Average		69.5	2.50	312.23
	Maximum		225.2	16.62	1345.70
	Minimum		26.8	0.40	43.94

Table A2.5 (cont)

WEEKLY COMPOSITED FILTER RESULTS
BUNKER HILL PROJECT - MIDDLE SCHOOL - KELLOGG, IDAHO
NOVEMBER 7, 1987 - NOVEMBER 7, 1988

Week No.	Composite Group No.	Week Ending Date	Average TSP Conc. (ug/scm)	Average Cadmium Conc. (ng/scm)	Average Lead Conc. (ng/scm)
1	54	871109	48.7	5.14	240.14
2	55	871116	30.0	2.67	203.49
3	56	871123	43.3	5.40	174.81
4	57	871130	35.0	1.18	68.04
5	58	871207	29.2	1.10	69.21
6	59	871214	22.5	1.99	91.37
7	60	871221	29.8	0.97	46.87
8	61	871228	59.3	1.10	64.20
9	62	880104	45.5	1.44	59.12
10	63	880111	31.5	0.59	34.42
11	64	880118	29.1	0.39	50.63
12	65	880125	59.7	0.82	81.34
13	66	880201	43.7	2.72	72.98
14	67	880208	44.2	1.30	59.24
15	68	880215	30.7	0.50	49.68
16	69	880222	83.1	2.95	296.97
17	70	880229	92.0	4.47	292.27
18	71	880307	30.7	0.93	78.44
19	72	880314	24.0	0.64	47.82
20	73	880321	46.1	1.69	142.00
21	74	880328	32.8	0.63	48.62
22	75	880404	21.7	0.53	35.43
23	76	880411	22.7	1.34	61.86
24	77	880418	38.8	1.22	121.00
25	78	880425	15.3	0.74	51.06
26	79	880502	20.0	1.64	84.26
27	80	880509	17.2	0.64	49.26
28	81	880516	51.1	2.85	185.51
29	82	880523	31.0	0.79	70.05
30	83	880530	22.3	0.63	38.37
31	84	880606	18.4	0.29	38.33
32	85	880613	20.1	0.40	31.13
33	86	880620	54.3	0.61	62.53
34	87	880627	38.5	0.63	52.41
35	88	880704	23.4	0.58	33.69
36	89	880711	18.6	0.46	41.61
37	90	880718	15.8	0.29	18.15
38	91	880725	37.3	0.46	45.58
39	92	880801	63.5	1.74	123.00
40	93	880808	35.2	0.56	55.16
41	94	880815	41.3	0.95	47.29
42	95	880822	54.2	3.30	183.46
43	96	880829	76.9	2.75	124.69
44	97	880905	53.5	1.60	102.34
45	98	880912	146.4	3.99	310.02
46	99	880919	47.2	1.64	68.17
47	100	880926	25.0	1.22	51.36
48	101	881003	34.3	0.89	51.22
49	102	881010	36.6	2.21	128.96
50	103	881017	64.6	3.01	194.08
51	104	881024	59.4	2.77	150.96
52	105	881031	46.9	2.18	104.09
53	106	881107	18.4	1.10	43.27
	Average		40.8	1.56	94.91
	Maximum		146.4	5.40	310.02
	Minimum		5.3	0.29	18.15

Appendix A3

Material referenced in Section 3

TABLE A3.1
Cumulative Distributions For Solid Media Lead Concentrations at Bunker Hill[(a)]

Lead Concentration ug/gm	Percentile: 1983 Mineral Soil (n=206)	1983 Soil Litter (n=28)	1983 House Dust (n=147)	1986/87 Mineral Soil (n=1161)	1986/87 Soil Litter (n=1152)	1988 House Dust (n=94)
60	0.5			0.1		
70						1.1
90						2.1
100						3.2
120		3.6				
130				0.3	0.1	4.3
150					0.3	
160	1.9			0.5		6.4
170						7.4
180	2.4					
210	3.4			0.7		8.5
220	4.4			0.9		
230	5.3	7.1	0.7	1.1		9.6
240				1.2	0.4	
250				1.6		
260	5.8	10.7				10.6
270	7.3			1.9	0.5	
280				2.0	0.6	
290	7.8			2.1	0.8	
300	8.7			2.2		
310	9.2				0.9	
320	9.7			2.3	1.0	
330	10.2			2.4		
340	10.7					
350	11.7			2.5	1.1	
360	12.1					
370	12.6			2.8		
380	13.6			2.9	1.2	
390	14.1	14.3		3.1	1.3	
400				3.3		
410	14.6			3.4		
420	15.5		1.4	3.6	1.4	
430	16.0			3.8		11.7
440				3.9		
450	16.5			4.0	1.6	12.8
460				4.1		
470				4.2	1.7	
480	17.0			4.5		13.8
490	18.0			4.6		
500	18.9			4.7	2.0	
510				4.9		
520				5.0	2.2	
530	19.9	17.9	2.7	5.1		
540	20.9		3.4	5.2		
550					2.3	
560			4.1	5.3		16.0
570				5.6		17.0
580	21.4	21.4		5.9		
590		25.0		6.1	2.5	
600	21.8		4.8	6.5	2.7	
610	22.3		5.4		2.8	18.1
620					3.0	
630	22.8			6.8	3.1	
640				7.1	3.2	
650					3.3	20.2
660			6.1	7.4	3.5	
670	23.8	28.6	6.8	7.8	3.6	
680	24.3			8.0		21.3
690	24.8	32.1		8.3	3.8	
700	25.2			8.5	3.9	22.3
710	25.7		8.2	8.9		
720				9.0	4.0	
730				9.1		
740	26.2		8.8	9.2	4.1	
750			10.2	9.4		
760	27.7			9.6	4.3	

TABLE A3.1 (Continued)
Cumulative Distributions For Solid Media Lead Concentrations at Bunker Hill[(a)]

Lead Concentration ug/gm	Percentile: 1983 Mineral Soil (n=206)	1983 Soil Litter (n=28)	1983 House Dust (n=147)	1986/87 Mineral Soil (n=1161)	1986/87 Soil Litter (n=1152)	1988 House Dust (n=94)
770	28.6			9.8	4.6	
780	29.1		10.9	10.2	4.8	23.4
790	30.6				5.1	
800				10.4		
810			11.6	10.6	5.2	
820	31.6	35.7	12.2	11.0	5.3	25.5
830	32.0			11.2	5.4	
840	32.5			11.5	5.5	
850	33.0		12.9	11.8	5.6	
860	33.5			12.1	5.8	
870			13.6	12.5	6.0	26.6
880				13.0	6.2	27.7
890			14.3	13.1		
900				13.4	6.4	28.7
910			15.6	13.8	6.6	
920				14.2	6.9	30.9
930	34.5		16.3		7.3	
940					7.5	
950	35.0		17.7	14.4	7.6	
960	35.4			14.6		
970			18.4	15.0	7.8	
980			19.0	15.2	8.0	
990	36.4		19.7	15.4	8.1	31.9
1000	37.4	39.3		15.6	8.2	33.0
1100	38.3		26.5	18.5	9.9	38.3
1200	39.8	42.9	27.9	21.4	11.5	43.6
1300	42.2		30.6	24.0	12.9	47.9
1400	44.7	50.0	32.0	27.4	14.5	54.3
1500	46.1		37.4	29.7	15.8	58.5
1600	47.6		40.1	32.9	16.9	62.8
1700	51.0		42.2	35.8	19.4	67.0
1800	52.4	53.6	44.2	38.8	21.0	71.3
1900	53.4		46.9	42.4	22.9	72.3
2000	55.3	57.1	51.0	44.2	25.4	76.6
2100	55.8		53.1	46.5	27.7	
2200	56.8		53.7	48.8	29.9	
2300	59.2	60.7	54.4	50.5	31.9	
2400	60.7		55.1	52.1	33.5	
2500	62.6		57.8	54.3	35.3	77.7
2600	63.6	64.3	59.9	56.4	36.8	
2700	64.6	71.4	63.9	58.1	38.6	78.7
2800	67.0		65.3	60.8	41.0	79.8
2900			67.3	62.8	42.6	81.9
3000	68.4	75.0	68.7	65.1	45.3	
3100	72.3		70.1	67.1	47.1	83.0
3200	72.8		70.7	68.5	49.2	
3300	74.3		71.4	70.7	51.0	84.0
3400	74.8		72.8	72.1	53.1	
3500	76.7		74.1	73.6	54.7	
3600	77.2	78.6	76.2	75.2	56.6	
3700	77.7		78.2	77.2	58.0	85.1
3800	79.1		80.3	78.1	59.8	86.2
3900	80.6		81.0	79.2	61.8	
4000	81.1	82.1	83.7	80.4	62.9	87.2
4100	81.6		85.0	81.0	65.1	88.3
4200			85.7	82.0	66.7	
4300	82.0		87.1	82.8	67.7	
4400	83.5		89.8	84.2	69.4	
4500		85.7	90.5	84.9	70.5	
4600	84.0		91.8	85.3	71.7	
4700				86.1	73.1	90.4
4800	84.5		92.5	86.9	74.2	
4900	85.4		93.2	87.7	75.3	
5000	86.9		94.6	88.0	76.3	
5100	88.3			88.5	77.6	
5200			95.2	89.2	78.4	

TABLE A3.1 (Continued)
Cumulative Distributions For Solid Media Lead Concentrations at Bunker Hill[a]

	Percentile					
Lead Concentration ug/gm	1983 Mineral Soil (n=206)	1983 Soil Litter (n=28)	1983 House Dust (n=147)	1986/87 Mineral Soil (n=1161)	1986/87 Soil Litter (n=1152)	1988 House Dust (n=94)
5300	89.3	89.3		89.9	79.6	
5400				90.4	80.8	
5500	89.8			90.8	81.5	
5600	90.3		96.6	91.1	82.6	
5700			97.3	91.8	83.2	
5800				92.3	84.1	
5900		92.9		92.5	84.7	
6000	91.3			93.0	85.4	91.5
6100	91.7			93.4	86.1	
6200	92.2			94.1	86.5	
6300	92.7			94.2	87.2	
6400				94.7	88.0	
6500	93.2			94.8	88.3	94.7
6600	93.7			95.0	88.8	
6700						89.2
6800				95.2	89.6	
6900				95.6	90.2	
7000				95.9	90.5	95.7
7100				96.0	90.8	
7200				96.6	91.5	
7300				96.7	91.8	
7400				96.8	92.0	
7500				96.9	92.3	
7600				97.0	92.5	
7700				97.1	92.6	
7800				97.2	92.8	
7900	94.7		98.0			92.9
8000	95.1			97.3	93.4	
8100	95.6			97.5	93.7	
8200			98.6	97.6		
8300				97.8	93.9	
8400				97.9	94.4	
8500				98.0	94.5	
8600	96.1			98.1	94.6	
8700				98.2		
8800				98.4		
8900				98.5	94.9	
9000				98.6	95.0	
9100			99.3		95.1	
9200				98.7		
9300					95.2	
9400					95.4	
9500		96.4		98.8	95.7	
9700				98.9	95.8	
9800	96.6				96.0	
9900				99.0	96.1	
10000					96.4	
11000	97.6		100.	99.2	97.3	
12000	98.1	100.		99.4	97.8	96.8
13000				99.6	98.3	
14000	98.5			99.7	99.0	
15000				99.8	99.2	
16000	99.0				99.3	
17000				99.9	99.5	
18000				100.	99.7	97.9
19000	99.5				99.8	
21000	100.					
22000					99.9	
25000						98.9
46500					100.	
52700						100.

(a) Source: IDHW 1989b
CH_2M Hill 1990b

TABLE A3.2 (from Protocol Document)
Estimated Mean Airborne Metals Concentrations
(μg/m³), 1971-1988

Location	Contaminant	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Rural Back-ground*
Smelterville	As	.07	.13	.20	.17	.11	.12	.11	.07	.08	.07	.06	.038	.010	.007	.010	.014	.017	.017	
	Cd	.35	.35	.34	.39	.18	.31	.27	.20	.30	.30	.30	.075	.018	.010	.016	.026	.031	.031	
	Cu	.10	.19	.28	.24	.15	.17	.16	.09	.11	.11	.08	.13	.10	.10	.10	.10	.11	.11	
	Pb	5.7	11.2	16.5	14.3	8.9	9.8	9.1	5.4	6.7	6.3	4.6	.88	.20	.12	.19	.30	.36	.36	
	Sb	.08	.16	.23	.20	.13	.14	.13	.08	.09	.09	.06	.022	.014	.013	.014	.015	.016	.016	
	Zn	3.9	7.7	11.4	9.9	6.1	6.7	6.3	3.7	4.6	4.3	3.2	.51	.14	.10	.14	.20	.23	.23	
Kellogg	As	.25	.29	.45	.42	.22	.23	.20	.16	.18	.18	.12	.012	.010	.008	.009	.010	.010	.008	
	Cd	.30	.35	.56	.42	.17	.26	.25	.29	.31	.46	.30	.022	.015	.009	.010	.015	.013	.009	
	Cu	.14	.16	.26	.23	.13	.13	.12	.092	.10	.10	.070	.14	.14	.14	.14	.14	.14	.14	
	Pb	8.2	9.6	15	14	7.4	7.5	6.8	5.4	5.9	5.9	4.1	.28	.19	.12	.13	.19	.17	.11	
	Sb	.11	.13	.21	.19	.10	.11	.10	.076	.083	.083	.057	.007	.005	.004	.004	.005	.005	.004	
	Zn	3.5	4.1	6.4	6.0	3.2	3.2	2.9	2.3	2.5	2.5	1.8	.16	.11	.08	.09	.11	.10	.08	
Pinehurst	As	.09	.09	.09	.09	.03	.04	.04	.05	.06	.06	.03	.002	.001	.001	.001	.001	.001	.001	.001
	Cd	.26	.26	.26	.26	.08	.13	.12	.16	.19	.19	.11	.014	.012	.008	.009	.009	.007	.007	.003
	Cu	.11	.11	.11	.11	.06	.06	.06	.05	.06	.04	.02	.003	.003	.002	.002	.002	.001	.001	.001
	Pb	6.1	6.1	6.1	6.1	3.1	3.4	3.6	2.7	3.1	2.2	1.2	.16	.14	.09	.10	.10	.08	.08	.045
	Sb	.09	.09	.09	.09	.03	.04	.04	.05	.06	.06	.04	.002	.001	.001	.001	.001	.001	.001	.001
	Zn	.47	.47	.47	.47	.14	.23	.22	.29	.34	.34	.20	.03	.03	.024	.024	.024	.024	.024	.024

Sources:
U.S. EPA 1989 l
Cooper et al. 1980
Ragaini et al. 1977
WCC 1986
Dames & Moore 1989 d
IDHW 1989 a
*PANORAMAS 1986

TABLE A3.3 (from Protocol Document)
Estimated Maximum 24-hour Metals Concentrations
($\mu g/m^3$), 1971-1988

Location	Contaminant	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Smelterville	As	0.55	2.02	1.48	1.85	1.52	1.00	1.10	1.14	0.89	1.23	0.46	0.28	0.07	0.03	0.10	0.07	0.05	0.05
	Cd	0.66	2.41	1.78	2.22	1.18	1.94	1.38	0.92	1.06	1.48	0.54	0.15	0.04	0.02	0.06	0.04	0.03	0.02
	Cu	2.12	7.74	5.69	7.10	5.85	3.82	4.20	4.39	3.41	4.73	1.75	1.09	0.27	0.13	0.40	0.25	0.19	0.19
	Pb	14.91	54.50	40.10	50.00	41.20	26.90	29.60	30.90	24.00	33.30	12.30	7.70	1.90	0.90	2.80	1.79	1.33	1.33
	Sb	0.40	1.47	1.08	1.35	1.11	0.73	0.80	0.83	0.65	0.90	0.33	0.21	0.05	0.02	0.08	0.05	0.04	0.04
	Zn	15.88	58.04	42.71	53.25	43.88	28.65	31.52	32.91	25.56	35.46	13.10	3.82	0.94	0.45	1.39	0.89	0.66	0.66
Kellogg	As	3.47	2.51	2.90	3.53	4.41	2.11	1.87	3.03	2.41	2.25	1.34	0.06	0.02	0.01	0.02	0.03	0.02	0.03
	Cd	4.01	2.89	3.35	2.00	3.08	1.54	1.68	3.79	1.80	2.61	1.61	0.05	0.02	0.01	0.01	0.02	0.01	0.02
	Cu	0.71	0.51	0.59	0.72	0.90	0.43	0.38	0.62	0.49	0.46	0.27	0.51	0.17	0.10	0.14	0.27	0.16	0.24
	Pb	41.80	30.20	34.90	42.50	53.10	25.40	22.50	36.50	29.00	27.10	16.10	2.10	0.70	0.40	0.60	1.12	0.67	1.01
	Sb	1.67	1.21	1.40	1.70	2.12	1.02	0.90	1.46	1.16	1.08	0.64	0.04	0.01	0.01	0.01	0.02	0.01	0.02
	Zn	21.74	15.70	18.15	22.10	27.61	13.21	11.70	18.98	15.08	14.09	8.37	1.15	0.38	0.22	0.33	0.61	0.37	0.55
Pinehurst	As	0.71	0.71	0.71	0.71	0.50	0.64	0.67	0.69	0.73	0.31	0.33	0.026	0.014	0.009	0.011	0.011	0.007	0.007
	Cd	0.97	0.97	0.97	0.97	0.71	1.24	0.59	1.54	2.16	1.26	0.59	0.006	0.003	0.002	0.002	0.002	0.002	0.002
	Cu	18.75	18.75	18.75	18.75	13.04	16.74	17.58	18.25	19.26	8.07	8.58	0.673	0.378	0.235	0.286	0.286	0.193	0.193
	Pb	22.30	22.30	22.30	22.30	15.50	19.90	20.90	21.70	22.90	9.60	10.20	0.800	0.450	0.280	0.340	0.340	0.230	0.230
	Sb	0.89	0.89	0.89	0.89	0.62	0.80	0.84	0.87	0.92	0.38	0.41	0.032	0.018	0.011	0.014	0.014	0.009	0.009
	Zn	98.32	98.32	98.32	98.32	68.34	87.74	92.15	95.68	101.0	42.33	44.97	3.527	1.984	1.235	1.499	1.499	1.014	1.014

Sources:
U.S. EPA 1989i
Cooper et al. 1980
Ragaini et al. 1977
WCC 1986
Dames & Moore 1989d
IDHW 1989a

Figure A3.1

1983 Bunker Hill Populated Areas
Distribution of Lead Concentration in Mineral Soils
for Smelterville, Kellogg, Wardner, Page and Pinehurst

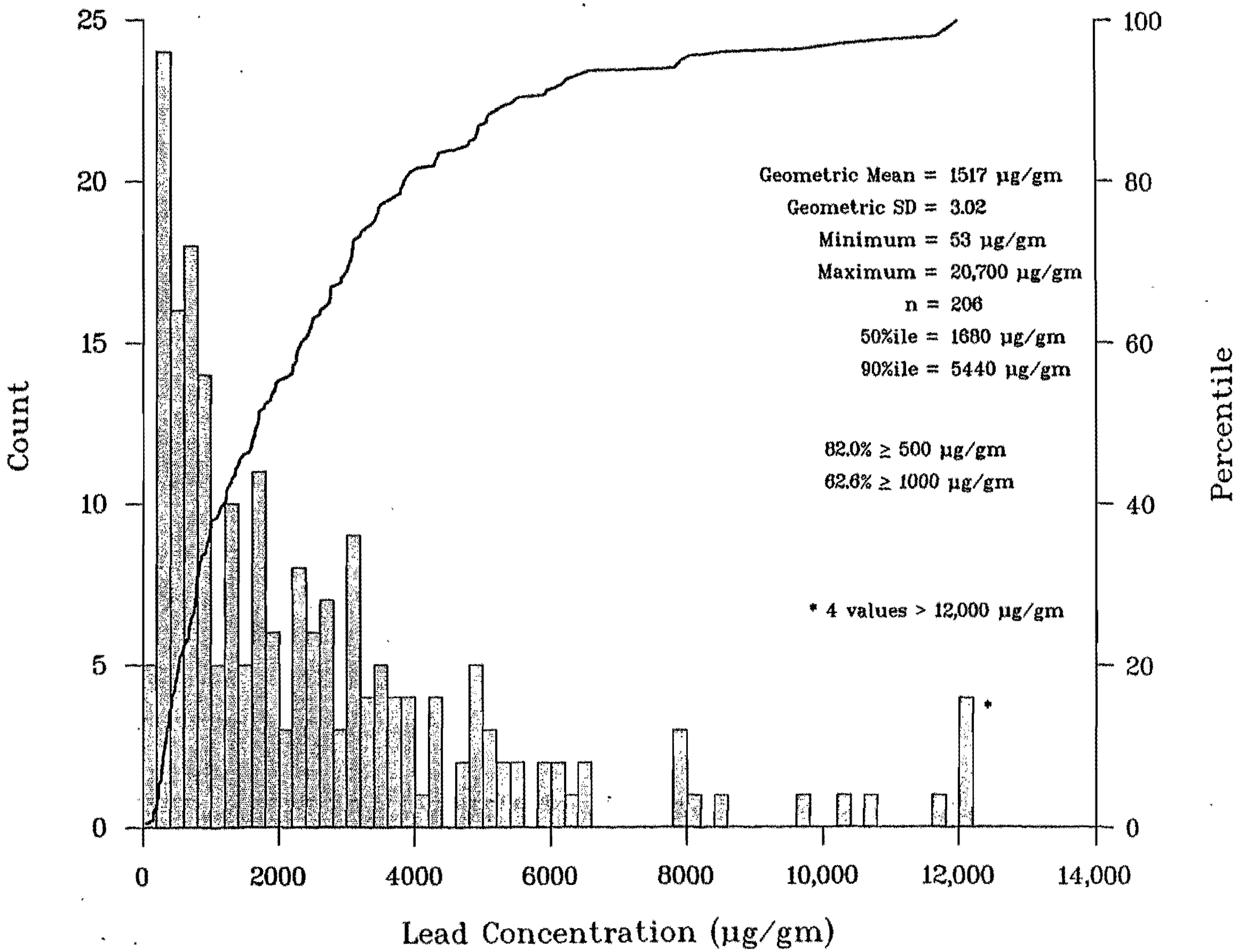


Figure A3.2

1986/1987 Bunker Hill Populated Areas
Distribution of Lead Concentration in Mineral Soils
for Smelterville, Kellogg, Wardner and Page

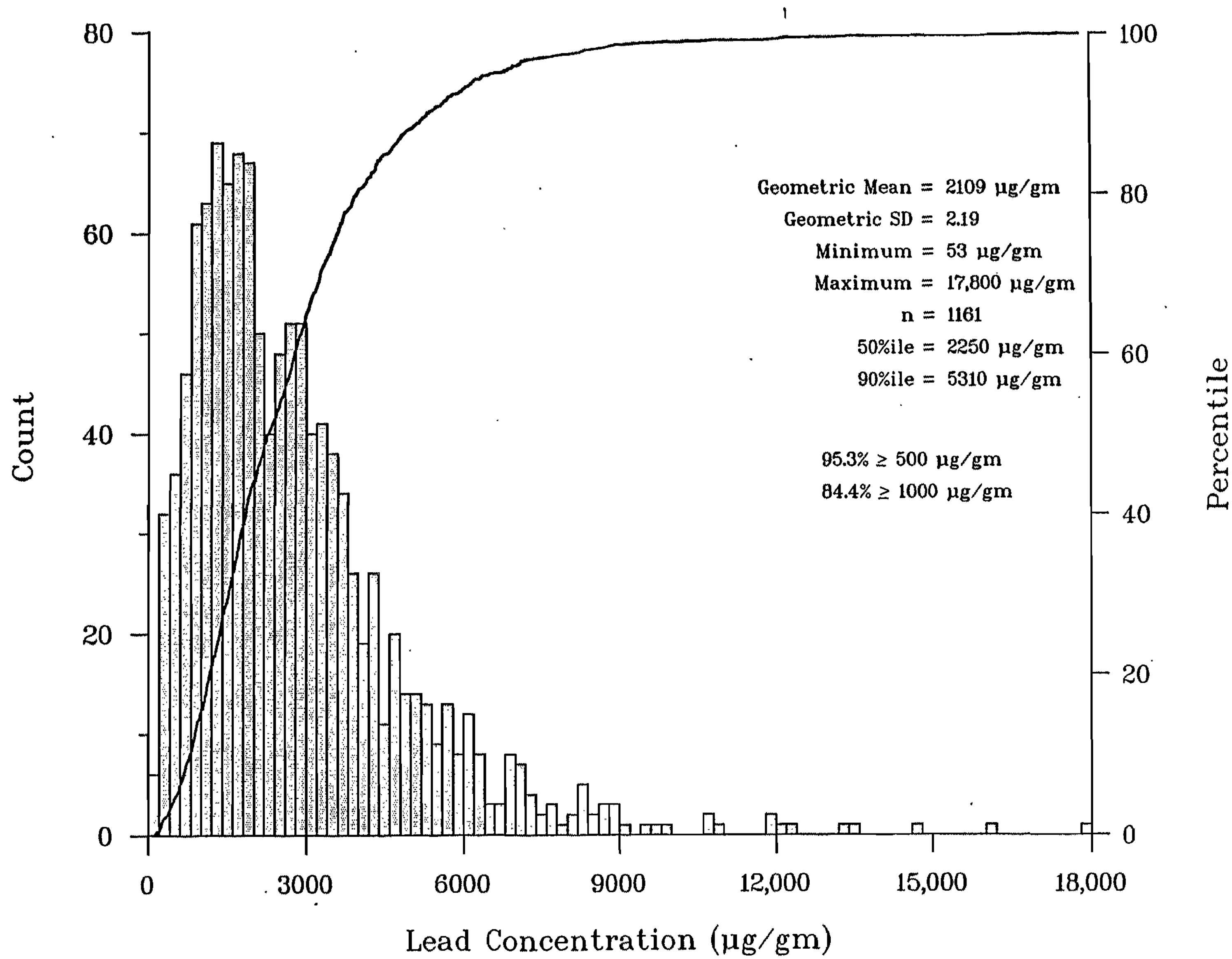


Figure A3.3

1986/1987 Bunker Hill Populated Areas
Distribution of Lead Concentration in Soil Litter
for Smelterville, Kellogg, Wardner and Page

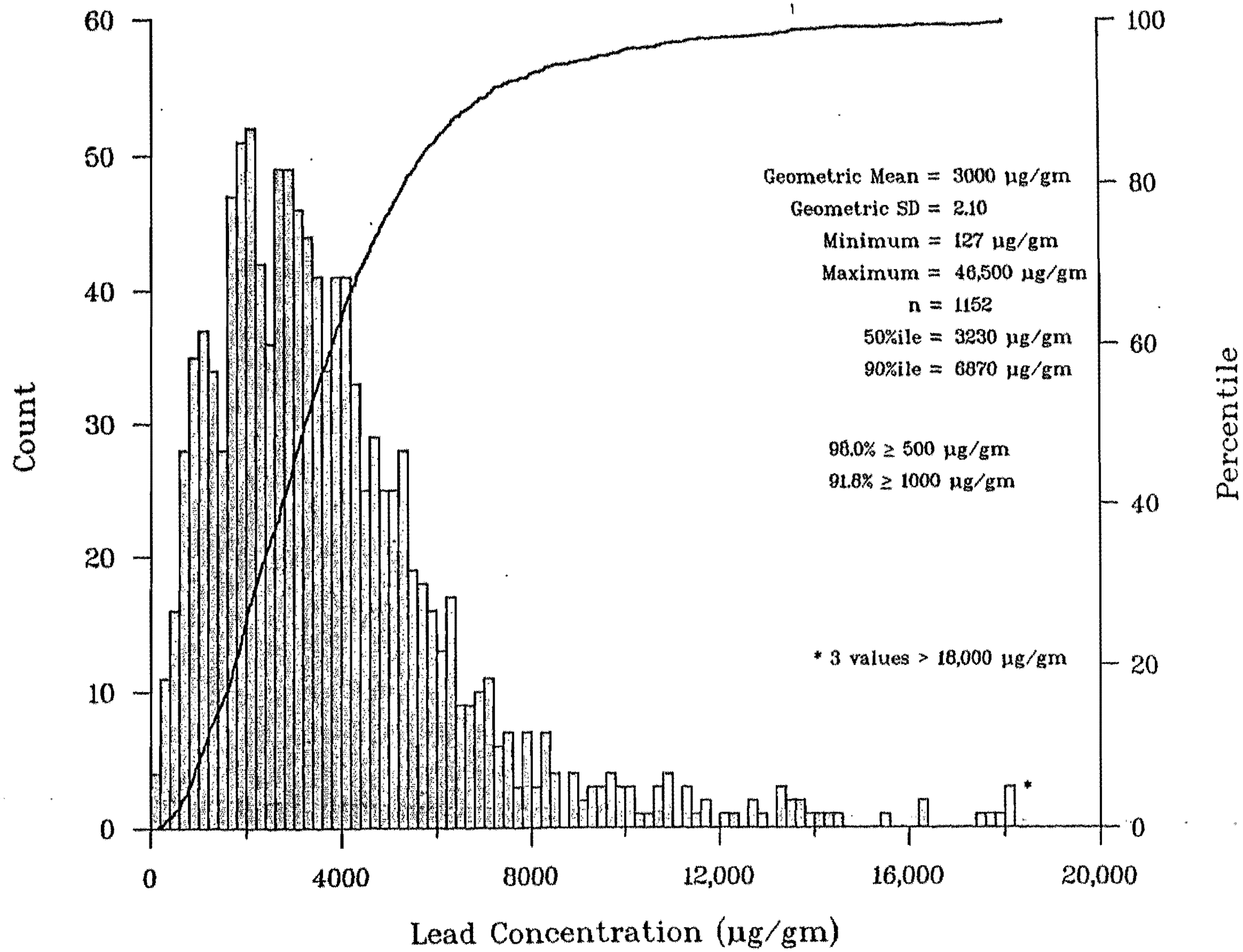


Figure A3.4

1983 Bunker Hill Populated Areas
Distribution of Lead Concentration in House Dusts
for Smelterville, Kellogg, Wardner, Page and Pinehurst

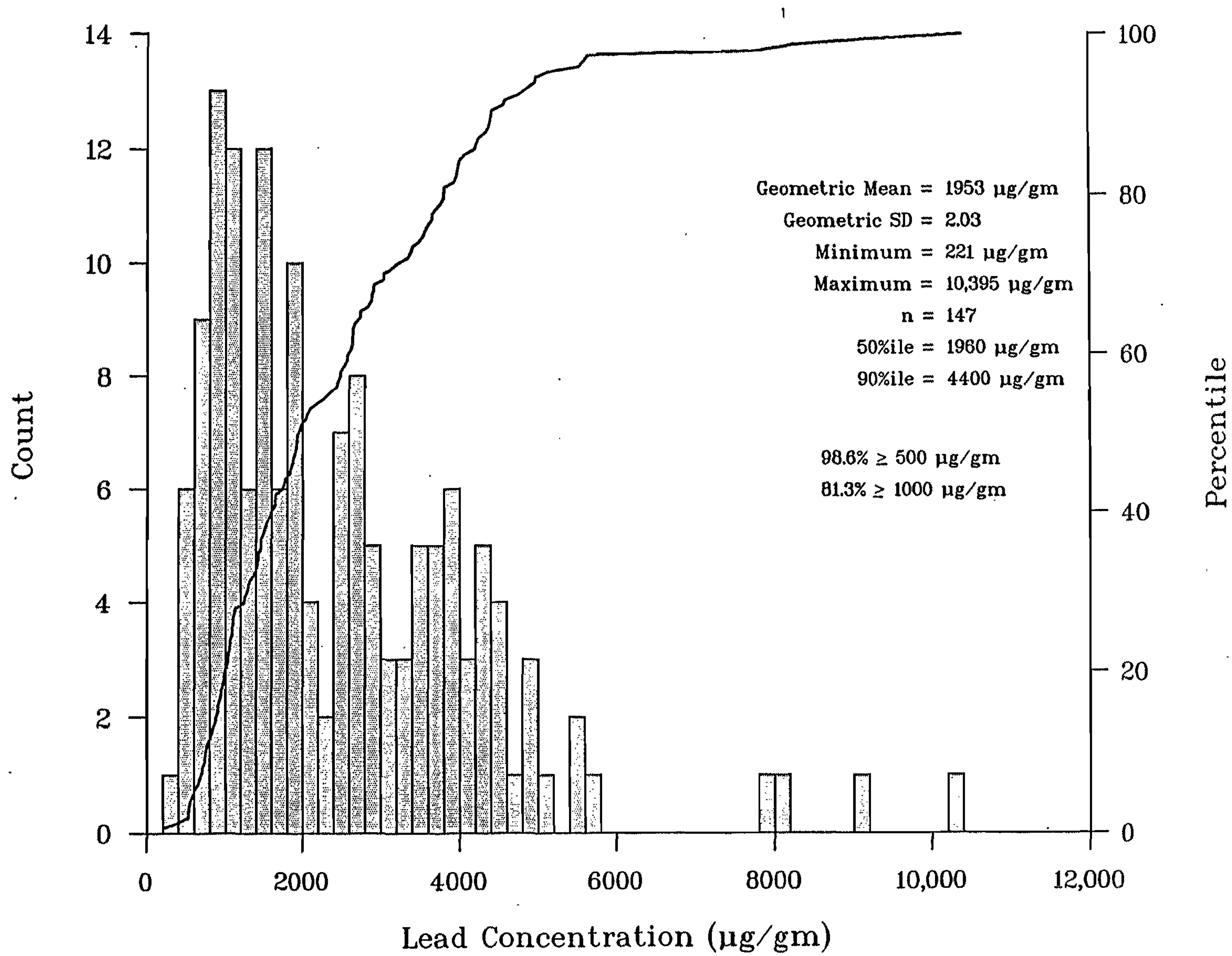
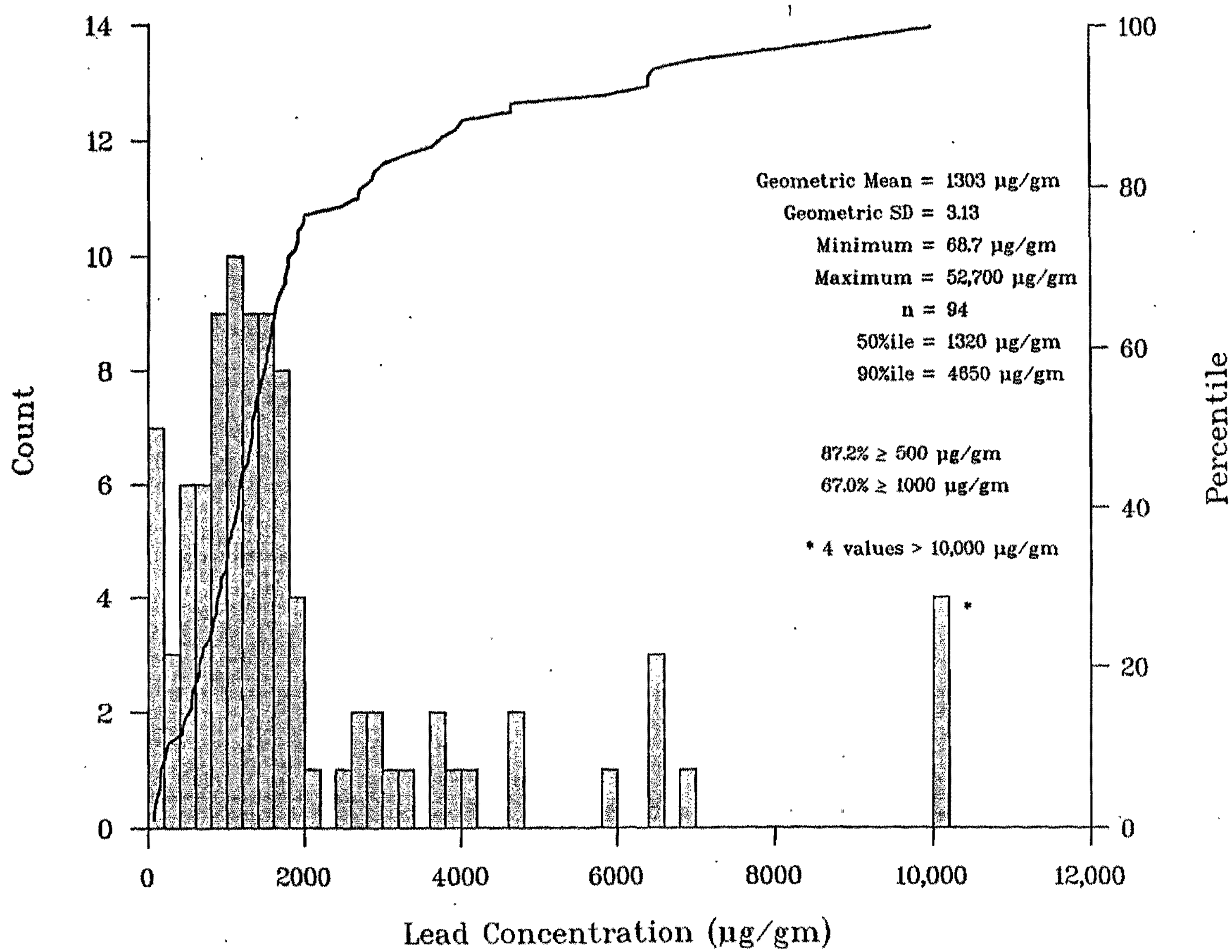


Figure A3.5

1988 Bunker Hill Populated Areas
Distribution of Lead Concentration in House Dusts
for Smelterville, Kellogg, Wardner and Page



Appendix A4

Material referenced in Section 4

TABLE A4.1 Fugitive Dust Source Identification and Characterization (Dames & Moore, 1990a)

SOURCE NUMBER	DESCRIPTION	AREA (acre)	EMISSION RATE (tons/acre/yr)	Pb (ppm)	Cd (ppm)	As (ppm)	TSP (TPY)	Total Emissions Pb (lbs/yr)	Cd (lbs/yr)	As (lbs/yr)
Kellogg Area:										
P01	I90/CDA CORRIDOR	158	0.0631	2697	22.6	51.6	10.00	53.94	0.45	1.03
P02	SUNNYSIDE AREA	134	0.0099	2593	21.6	52.7	1.33	6.90	0.06	0.14
P03	KELLOGG HIGH SCHOOL	34	0.0265	2614	21.9	54.7	0.89	4.65	0.04	0.10
P04	OLD TOWN/WARDNER	271	0.0071	2800	23.7	50.5	1.92	10.75	0.09	0.19
P05	VACANT LOT	9	0.0183	19900	30.8	250.0	0.17	6.85	0.01	0.09
P06	UNDEVELOPED AREA	12	0.0352	1813	17.1	63.9	0.44	1.58	0.01	0.06
P07	KELLOGG JR. HIGH	24	0.0289	1813	17.1	63.9	0.69	2.48	0.02	0.09
P08	SHOSHONE APTS.	5	0.0195	49064	47.8	235.0	0.10	9.91	0.01	0.05
AREA TOTAL		648					15.53	97.05	0.70	1.74
Smelterville Area:										
P10	SMELTERVILLE	90	0.0075	3499	39.4	59.4	0.68	4.72	0.05	0.08
P11	W. SMELTERVILLE	17	0.0676	3499	39.4	59.4	1.17	8.19	0.09	0.14
AREA TOTAL		107					1.85	12.91	0.15	0.22
Pinehurst Area:										
P12	CDA/PINE CR. CONFL.	238	0.0304	11000	NA	NA	7.25	159.50	0.00	0.00
P13	PINE CR. CHANNEL	196	0.0516	1340	NA	NA	10.10	27.07	0.00	0.00
P14	PINEHURST	566	0.0016	500	NA	NA	0.89	0.89	0.00	0.00
AREA TOTAL		1001					18.24	187.46	0.00	0.00
Hillsides:										
U01	NW HILLSIDE	297	0.0280	704	12.8	39.7	8.31	11.70	0.21	0.66
U02	NW HILLSIDE	368	0.0086	843	13.1	46.3	3.16	5.33	0.08	0.29
U03	N HILLSIDE	928	0.0261	970	9.1	33.7	24.20	46.95	0.44	1.63
U04	N HILLSIDE	82	0.0169	807	7.7	31.4	1.38	2.23	0.02	0.09
U05	N HILLSIDE	61	0.0184	713	11.1	25.3	1.12	1.60	0.02	0.06
U06	N HILLSIDE	36	0.0144	238	7.5	31.7	0.52	0.25	0.01	0.03
U07	N HILLSIDE	35	0.0431	1300	14.1	34.6	1.49	3.87	0.04	0.10
U08	N HILLSIDE	80	0.0196	647	8.7	32.9	1.56	2.02	0.03	0.10
U09	N HILLSIDE	171	0.0110	1100	13.1	38.7	1.88	4.14	0.05	0.15
U10	N HILLSIDE	92	0.0366	1500	10.8	44.2	3.38	10.14	0.07	0.30
U11	N HILLSIDE	73	0.0127	1300	10.0	40.2	0.93	2.42	0.02	0.07
U12	N HILLSIDE	136	0.0087	924	9.6	45.9	1.18	2.18	0.02	0.11
U13	N HILLSIDE	124	0.0050	360	8.4	35.7	0.61	0.44	0.01	0.04
U14	N HILLSIDE	29	0.0260	1110	6.6	44.8	0.75	1.67	0.01	0.07
U15	N HILLSIDE	205	0.0201	1030	9.6	37.6	4.13	8.51	0.08	0.31
U16	NE HILLSIDE	171	0.0078	875	4.6	48.1	1.33	2.33	0.01	0.13
U17	NE HILLSIDE	369	0.0146	1100	5.5	104.0	5.41	11.90	0.06	1.13
U18	NE HILLSIDE	389	0.0088	976	10.0	28.2	3.43	6.70	0.07	0.19
U19	NE HILLSIDE	523	0.0249	2150	13.2	35.7	13.00	55.90	0.34	0.93
U20	SE HILLSIDE	1531	0.0373	2360	12.6	81.0	57.10	269.51	1.44	9.25
U21	SE HILLSIDE	403	0.0451	1830	10.4	34.3	18.20	66.61	0.38	1.25
U22	S HILLSIDE	188	0.0487	3640	8.4	22.8	9.15	66.61	0.15	0.42
U23	S HILLSIDE	162	0.0363	316	8.7	27.2	5.89	3.72	0.10	0.32
U24	S HILLSIDE	154	0.0361	344	7.9	11.0	5.57	3.83	0.09	0.12
U25	S HILLSIDE	195	0.0632	1110	9.7	29.6	12.30	27.31	0.24	0.73
U26	S HILLSIDE	119	0.0230	293	10.3	24.2	2.74	1.61	0.06	0.13
U27	S HILLSIDE	112	0.0307	142	6.6	37.9	3.44	0.98	0.05	0.26
U28	S HILLSIDE	101	0.0447	171	5.5	26.9	4.53	1.55	0.05	0.24
U29	S HILL/NEAR SMELTER	103	0.0682	1160	17.7	56.1	7.03	16.31	0.25	0.79
U30	S HILL/NEAR SMELTER	102	0.0778	338	8.4	33.4	7.94	5.37	0.13	0.53
U31	S HILL/NEAR SMELTER	92	0.0364	14400	34.2	193.0	3.36	96.77	0.23	1.30
U32	S HILL/NEAR SMELTER	101	0.0420	866	13.1	56.9	4.25	7.36	0.11	0.48
U33	S HILLSIDE	151	0.0617	375	9.4	18.3	9.31	6.98	0.18	0.34
U34	S HILLSIDE	244	0.0566	567	11.9	27.4	13.80	15.65	0.33	0.76
U35	S HILLSIDE	180	0.0465	490	8.7	30.5	8.36	8.19	0.15	0.51
U36	S HILLSIDE	351	0.0305	1490	9.2	32.1	10.70	31.89	0.20	0.69
U37	SW HILLSIDE	807	0.0255	722	8.6	35.1	20.60	29.75	0.35	1.45
U38	SW HILLSIDE	670	0.0139	307	6.2	29.1	9.34	5.73	0.12	0.54
U39	SW HILLSIDE	746	0.0194	2320	18.2	50.0	14.50	67.28	0.53	1.45
AREA TOTAL		10684					305.88	913.26	6.72	27.95
Bunker Hill Smelter Complex:										
U49	NEAR SHOSHONE	31	0.0414	49064	47.8	235.0	1.27	124.62	0.12	0.60
U50	WTR TRT PLANT	14	0.0390	43400	944.0	1178.0	0.54	46.79	1.02	1.27
U51	WAREHOUSE AREA	34	0.0287	232250	11115.0	9533.0	0.97	451.49	21.61	18.53
U52	BUNKER CR CORRIDOR	43	0.0613	19311	123.0	450.0	2.62	101.19	0.64	2.36

SOURCE NUMBER	DESCRIPTION	AREA (acre)	EMISSION RATE (tons/acre/yr)	Pb (ppm)	Cd (ppm)	As (ppm)	TSP (TPY)	Total Emissions Pb (lbs/yr)	Cd (lbs/yr)	As (lbs/yr)
U53	OLD HOMESITES	25	0.1446	21058	178.3	449.0	3.68	154.99	1.31	3.30
U54	OLD GYP OND	25	0.0051	62034	186.0	557.0	0.13	15.88	0.05	0.14
U55	PB SMELT COMPLEX	99	0.0161	172400	7560.0	3586.0	1.60	551.68	24.19	11.48
U56A	NEAR GOV GULCH	54	0.0650	5660	43.6	100.0	3.52	39.85	0.31	0.70
U56B	NEAR GOV GULCH	43	0.0835	6270	66.9	107.0	3.59	45.02	0.48	0.77
U57A	ZN PLT COMPLEX	40	0.0911	5630	181.0	300.0	3.67	41.32	1.33	2.20
U57B	ZN PLT COMPLEX	16	0.0923	1810	81.3	80.0	1.46	5.29	0.24	0.23
U57C	ZN PLT COMPLEX	39	0.0425	6016	243.0	352.0	1.66	19.97	0.81	1.17
U72A	S NEAR SMELTER	131	0.0358	2600	24.5	51.8	4.70	24.44	0.23	0.49
U72B	S NEAR SMELTER	73	0.0271	12700	107.0	231.0	1.99	50.55	0.43	0.92
U72C	SE NEAR SMELTER	63	0.0302	3780	21.7	160.0	1.91	14.44	0.08	0.61
U72D	SE NEAR SMELTER	18	0.0289	3710	245.0	90.7	0.53	3.92	0.26	0.10
U73A	SE NEAR SMELTER	123	0.0341	2010	15.1	43.8	4.20	16.88	0.13	0.37
U73B	SE NEAR SMELTER	64	0.0297	1710	11.9	46.7	1.90	6.50	0.05	0.18
AREA TOTAL		936					39.94	1714.81	53.27	45.41
Smelterville Flats:										
U40	I90 R.O.W.	8	0.0691	515	15.8	41.3	0.55	0.56	0.02	0.05
U41	I90 R.O.W.	8	0.0433	1040	19.2	67.7	0.34	0.71	0.01	0.05
U42	I90 R.O.W.	8	0.0242	1370	23.1	60.0	0.19	0.52	0.01	0.02
U43	I90 R.O.W.	8	0.0138	849	15.2	82.9	0.12	0.20	0.00	0.02
U44	I90 R.O.W.	7	0.0248	1680	18.0	106.0	0.18	0.60	0.01	0.04
U58	CDA CHAN NO I90	71	0.0570	10000	NA	NA	4.04	80.80	0.00	0.00
U59	LINFOR LUMBER	35	0.0574	13667	193.0	198.0	2.03	55.49	0.78	0.80
U60	OUTDOOR THEATER	80	0.0700	9188	57.0	226.0	5.62	103.27	0.64	2.54
U61	AIRPORT AREA	218	0.1626	15964	51.0	209.0	35.40	1130.25	3.61	14.80
U62	FOREST PRODUCTS	140	0.1190	17362	63.0	269.0	16.70	579.89	2.10	8.98
U63	CDA CH NO OF AIRPORT	147	0.0140	6148	28.0	277.0	2.06	25.33	0.12	1.14
U64	FAIRGROUNDS	27	0.0598	12105	27.0	119.0	1.61	38.98	0.09	0.38
AREA TOTAL		758					68.83	2016.60	7.39	28.82
Page Pond:										
U65A	W PAGE SWAMP	56	0.0219	13654	44.7	76.0	1.22	33.32	0.11	0.19
U65B	E PAGE SWAMP	56	0.0000	0	0.0	0.0	0.00	0.00	0.00	0.00
U66	SMV GRAVEL PIT	14	0.0900	6000	NA	NA	1.29	15.48	0.00	0.00
U67	PAGE POND DIKES	49	0.1208	4348	39.0	202.0	5.94	51.65	0.46	2.40
U68	SOUTH FORK STP	38	0.0000	0	0.0	0.0	0.00	0.00	0.00	0.00
AREA TOTAL		213					8.45	100.45	0.57	2.59
Central Impoundment Area:										
U69A	CIA BEACHES	97	0.1093	1102	26.0	896.0	10.60	23.36	0.55	19.00
U69B	CIA DIKES	65	0.0529	12170	74.0	386.0	3.44	83.73	0.51	2.66
U70	GYPSUM POND/DIKES	56	0.1074	2162	24.0	188.0	6.00	25.94	0.29	2.26
U71	SLAG PILE	49	0.1218	10738	192.0	463.0	5.93	127.35	2.28	5.49
AREA TOTAL		267					25.97	260.39	3.63	29.40
Piles:										
H1	W OF CONC BLDG	0.003	0.0351	49000	866.0	5780:0	0.00	0.01	0.00	0.00
H2	N OF CONC BLDG	0.092	0.1272	30900	587.0	776.0	0.01	0.72	0.01	0.02
H3	CROSBY POINT	0.110	0.0817	61100	1520.0	11200.0	0.01	1.10	0.03	0.20
H4	MAGNET GULCH STOR	0.690	0.0963	396000	14900.0	106000.0	0.07	52.59	1.98	14.08
H5	NORBLO BAGHOUSE	0.018	0.1071	370000	20500.0	122000.0	0.00	1.46	0.08	0.48
H6	BLAST FURN AREA	0.230	0.0338	497000	4710.0	16600.0	0.01	7.72	0.07	0.26
H7	BLAST FURN BLDG	0.003	0.0331	135000	776.0	7000.0	0.00	0.03	0.00	0.00
H8	BOULEVARD AREA	5.517	0.0732	90400	831.0	13500.0	0.40	73.04	0.67	10.91
H9	WHEELABRATOR BAGHSE	0.014	0.1805	472000	54400.0	160000.0	0.00	2.35	0.27	0.80
H10	CD PLANT TANKS	0.026	0.0366	293000	42000.0	9490.0	0.00	0.57	0.08	0.02
H11	CELL ROOM	1.379	0.0102	20800	27.8	80.6	0.01	0.58	0.00	0.00
H12	SWEENEY POND CLEAROUT	0.230	0.0731	159000	26700.0	3740.0	0.02	5.34	0.90	0.13
H13	STORAGE AREA W PB SMELT	0.690	0.0183	315000	8610.0	9900.0	0.01	7.94	0.22	0.25
AREA TOTAL		9.003					0.55	153.46	4.31	27.14
ENTIRE SITE TOTAL		14622					485.24	5456.40	76.74	163.26

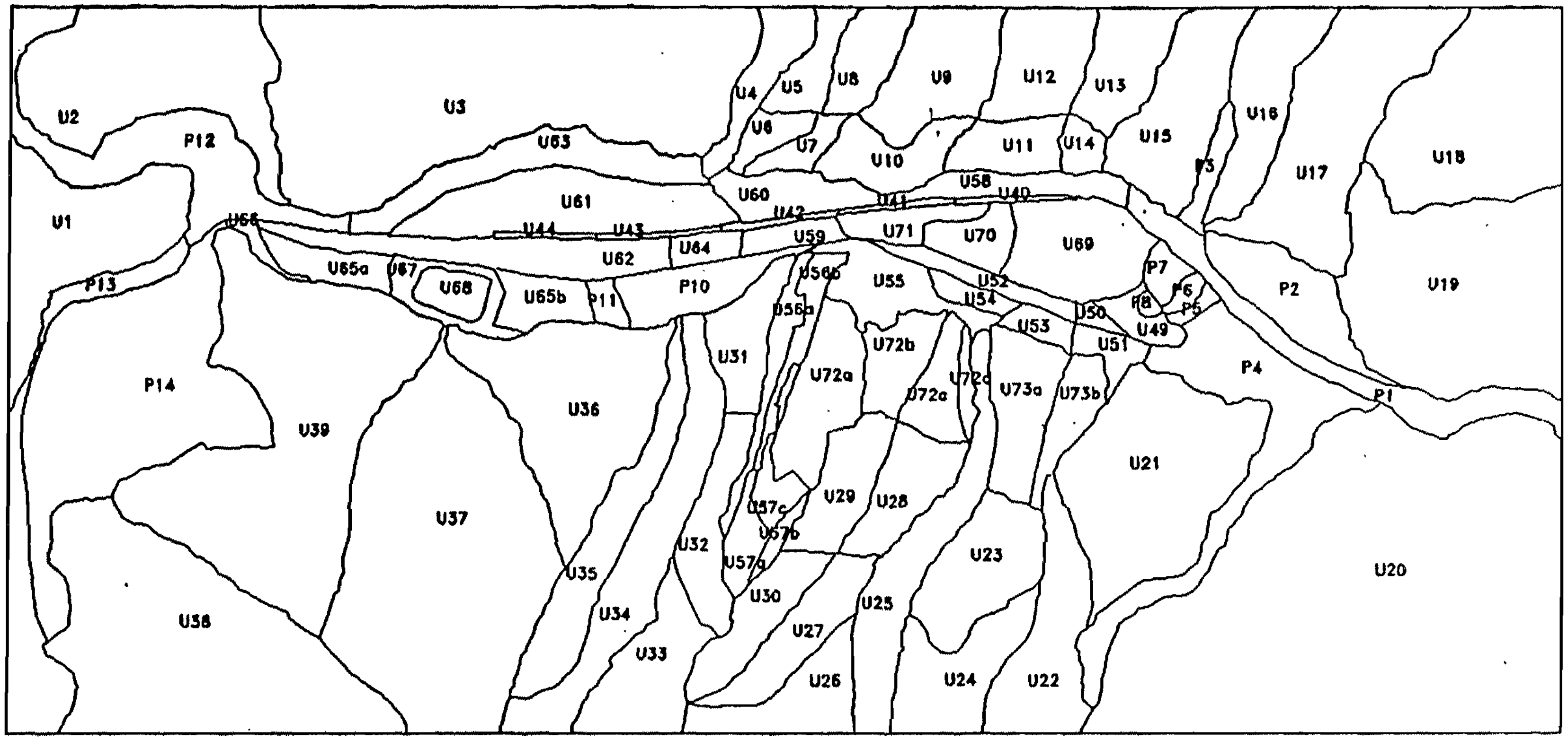


FIGURE A4.1 Fugitive Dust Source Area Identification

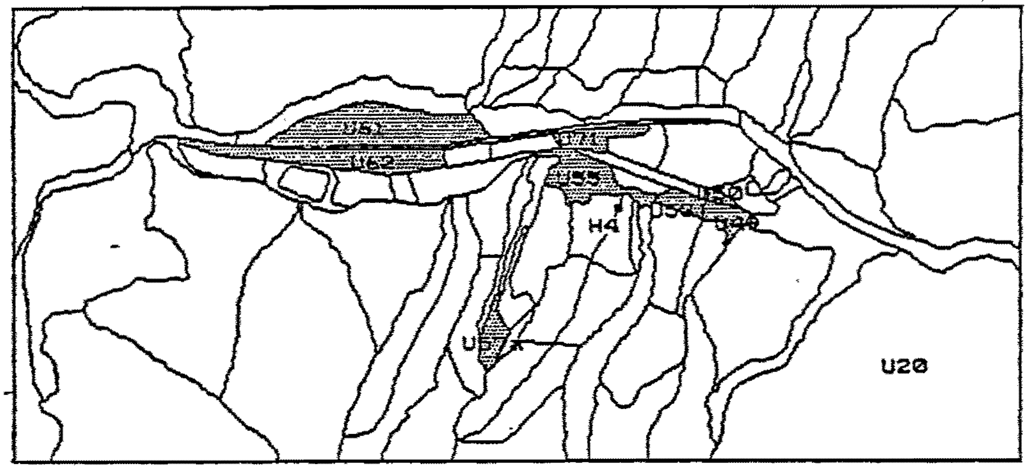


Figure A4.2

Largest Fugitive Dust Sources Ranked by Total Cadmium Emissions

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/yr)	Pb - - -	Cd (lbs/yr)	As - - -
U55	PB SMELTER COMPLEX	99	1.6	552	24.2	11.5
U51	WAREHOUSE AREA	34	1.0	451	21.6	18.5
U61	AIRPORT AREA	218	35.4	1130	3.6	14.8
U71	SLAG PILE	49	5.9	127	2.3	5.5
U62	FOREST PRODUCTS	140	16.7	580	2.1	9.0
H4	MAGNET GULCH STORAGE	0.7	0.1	53	2.0	14.1
U20	SE HILLSIDE	1531	57.1	270	1.4	9.3
U57A	ZN PANT COMPLEX	40	3.7	41	1.3	2.2
U53	OLD HOMESITES	25	3.7	155	1.3	3.3
U50	WATER TREATMENT PLANT	14	0.5	47	1.0	1.3

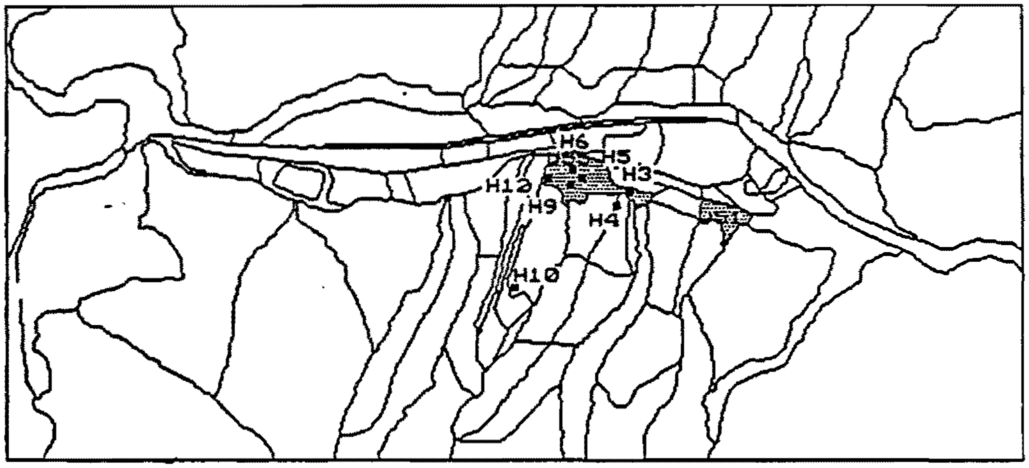


Figure A4.3

Largest Fugitive Dust Sources Ranked by Cadmium Emission Rate

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/acre/yr)	Pb	Cd	As
				- -	(lbs/acre/yr)	- -
H9	WHEELABRATOR BAGHOUSE	0.01	0.18	170.42	19.64	57.77
H5	NORBLO BAGHOUSE	0.02	0.11	79.27	4.39	26.14
H4	MAGNET GULCH STORAGE	0.69	0.10	76.25	2.87	20.41
H6	BLAST FURNACE AREA	0.23	0.03	33.60	0.32	1.12
H12	SWEENEY POND CLEAROUT	0.23	0.07	23.24	3.90	0.55
H10	CD PLANT TANKS	0.03	0.04	21.46	3.08	0.69
U51	WAREHOUSE AREA	33.85	0.03	13.34	0.64	0.55
H8	BOULEVARD AREA	5.52	0.07	13.24	0.12	1.98
H13	STORAGE AREA W PB SMELTER	0.69	0.02	11.51	0.31	0.36
H3	CROSBY POINT	0.11	0.08	9.98	0.25	1.83

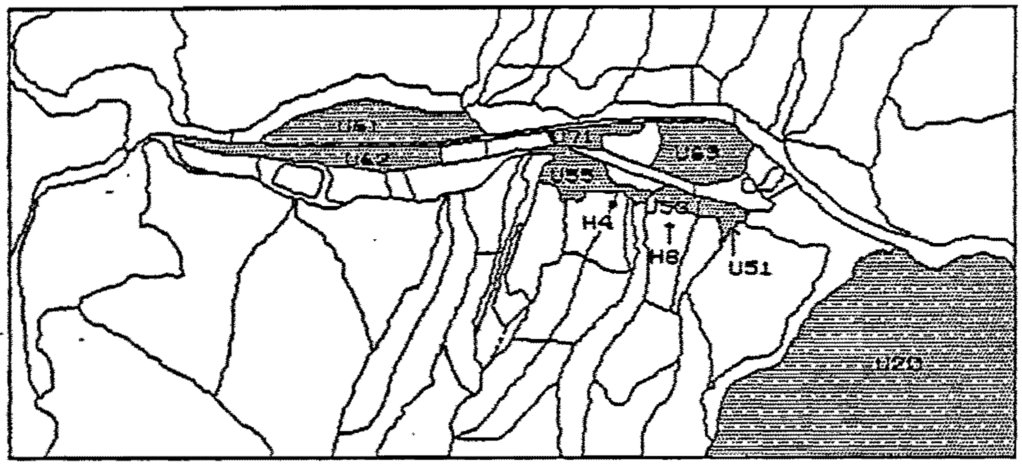


Figure A4.4

Largest Fugitive Dust Sources Ranked by Total Arsenic Emissions

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/yr)	Pb - - -	Cd (lbs/yr)	As - - -
U69A	CIA BEACHES	97	10.6	23	0.6	19.0
U51	WAREHOUSE AREA	34	1.0	451	21.6	18.5
U61	AIRPORT AREA	218	35.4	1130	3.6	14.8
H4	MAGNET GULCH STORAGE	0.7	0.1	53	2.0	14.1
U55	PB SMELTER COMPLEX	99	1.6	552	24.2	11.5
H8	BOULEVARD AREA	6	0.4	73	0.7	10.9
U20	SE HILLSIDE	1531	57.1	270	1.4	9.3
U62	FOREST PRODUCTS	140	16.7	580	2.1	9.0
U71	SLAG PILE	49	5.9	127	2.3	5.5
U53	OLD HOMESITES	25	3.7	155	1.3	3.3

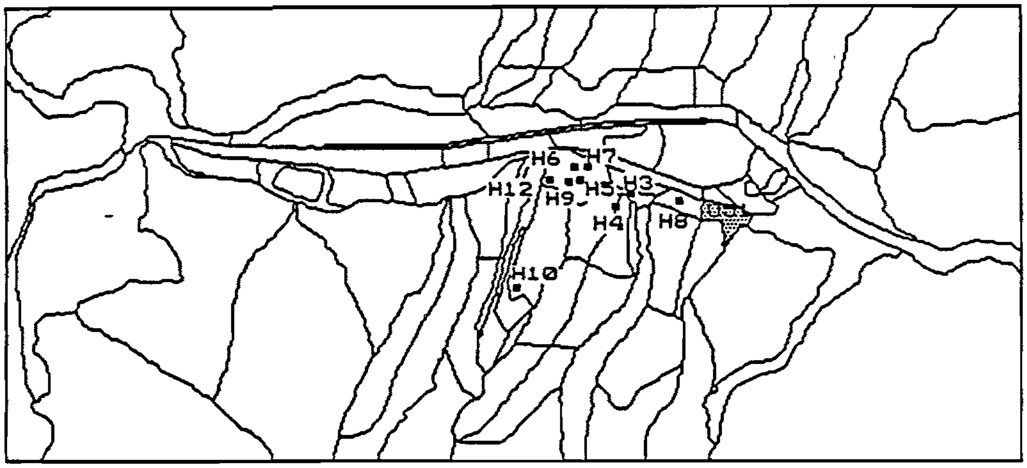


Figure A4.5

Largest Fugitive Dust Sources Ranked by Arsenic Emission Rate

SOURCE NUMBER	DESCRIPTION	AREA (acre)	TSP (tons/acre/yr)	Pb	Cd	As
				- - (lbs/acre/yr) - -		
H9	WHEELABRATOR BAGHOUSE	0.01	0.18	170.42	19.64	57.77
H5	NORBLO BAGHOUSE	0.02	0.11	79.27	4.39	26.14
H4	MAGNET GULCH STORAGE	0.69	0.10	76.25	2.87	20.41
H8	BOULEVARD AREA	5.52	0.07	13.24	0.12	1.98
H3	CROSBY POINT	0.11	0.08	9.98	0.25	1.83
H6	BLAST FURN AREA	0.23	0.03	33.60	0.32	1.12
H10	CD PLANT TANKS	0.03	0.04	21.46	3.08	0.69
U51	WAREHOUSE AREA	33.85	0.03	13.34	0.64	0.55
H12	SWEENEY POND CLEAROUT	0.23	0.07	23.24	3.90	0.55
H7	BLAST FURNACE BUILDING	0.00	0.03	8.93	0.05	0.46

TABLE A4.2

GULLY DATA FROM DAMES & MOORE MAY 1990 -
TABLE 2.1 SOIL LOSS COMPUTATIONS USING USLE

AREA NO.	DRAINAGE AREA (acres)	SOIL LOSS (tons/acre/yr)	TOTAL LOSS (tons/year)
1	129.3	36	4663
2	188.2	83	15670
3	166.4	31	5164
4	87.0	58	5062
5	218.9	53	11560
6	122.9	114	14043
7	473.6	63	30030
8	109.4	39	4281
9	222.1	100	22263
10	115.2	174	20039
11	124.2	226	28067
12	36.5	213	7791
13	51.2	195	9959
14	49.3	173	8551
15	59.5	210	12513
16	96.6	96	9301
17	165.1	54	8974
18	121.6	240	29184
19	164.5	152	24954
20	134.4	81	10884
21	103.0	254	26197
22	163.8	228	37342
23	206.0	359	73857
24	42.9	329	14133
25	185.0	347	64156
26	177.9	136	24151
27	143.4	108	15430
28	217.0	192	41633
29	165.1	49	8166
30a	73.0	17	1210
30b	25.0	35	876
30c	69.1	56	3876
31	149.8	24	3568
32	118.4	177	20964
33	98.6	16	1533
34	249.6	84	20964
35	149.1	112	16702
36	97.9	16	1604
37	151.0	32	4813
38	105.6	19	1973
39	60.2	65	3908
40	82.6	17	1402
41	78.1	19	1505
42	110.7	100	11052
43	121.6	40	4809
44	125.4	25	3156
45	37.8	14	534
46	80.6	31	2516
47	262.4	13	3372

TABLE A4.2 (Continued)

GULLY DATA FROM DAMES & MOORE MAY 1990 -
TABLE 2.1 SOIL LOSS COMPUTATIONS USING USLE

AREA NO.	DRAINAGE AREA (acres)	SOIL LOSS (tons/acre/yr)	TOTAL LOSS (tons/year)
48	98.6	77	7551
49	124.8	29	3570
50	90.6	34	3087
51	147.2	13	1982
52	156.2	38	5969
53	169.6	43	7260
54	117.1	35	4063
55	57.2	26	1487
56	60.8	14	877
57	51.2	17	872
58	27.5	15	405
59	64.0	15	958
60	46.1	19	859
61	89.0	14	1216
62	30.1	38	1134
63	84.5	23	1936
64	57.6	33	1910
65	117.8	33	3915
66	42.9	33	1429
67	146.6	31	4492
68	78.7	48	3770
69	237.4	48	11347
70	26.9	43	1154
71	53.1	25	1334
72	186.9	51	9495
73	120.3	27	3292
74	177.9	34	6069
75	111.4	76	8458
76	110.1	42	4618
77	166.4	39	6567
78	49.3	213	10480
79	220.8	2	521
80	310.4	1	458
	10115.5	6535	820891

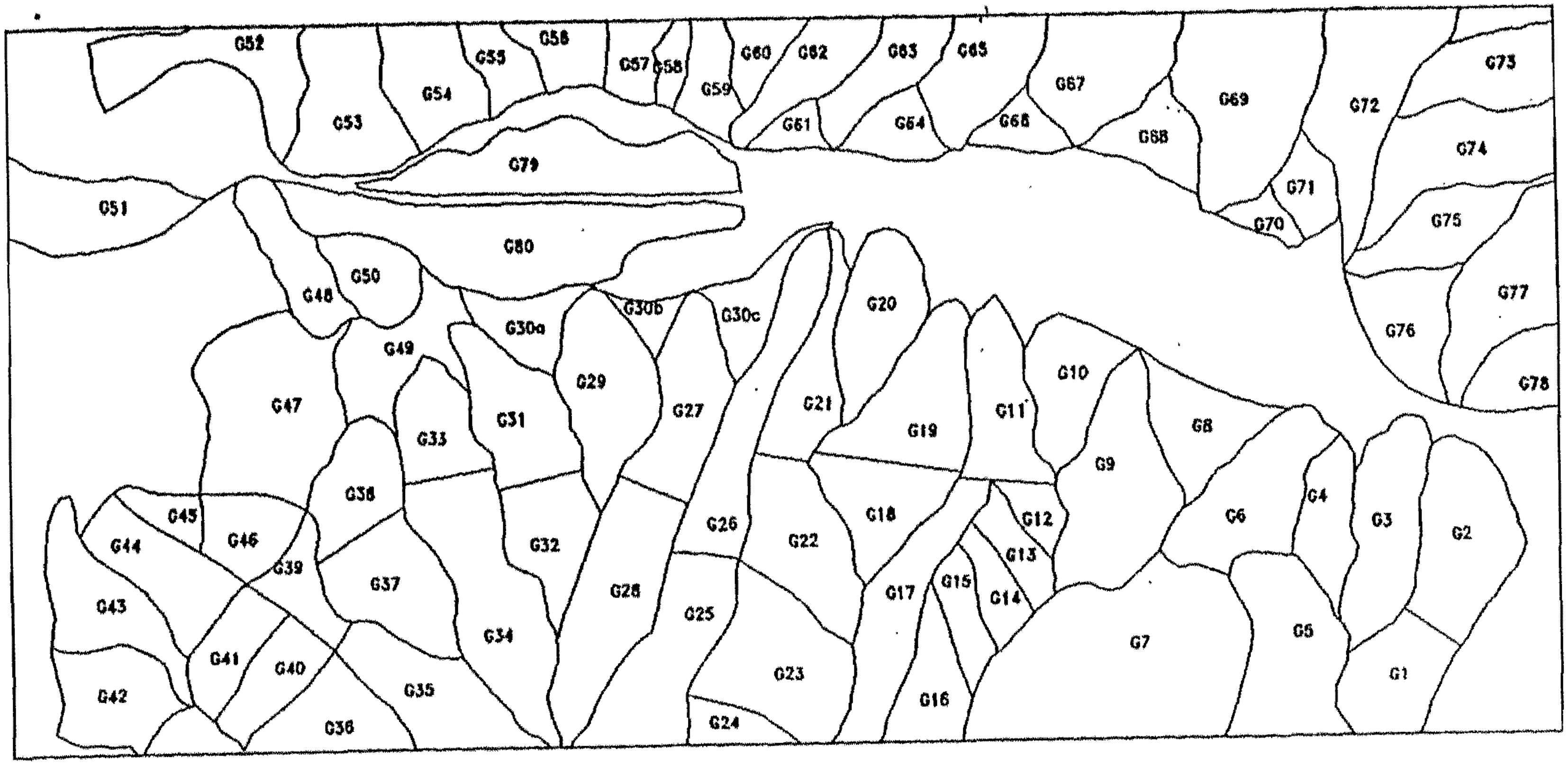


Figure A4.6 - Gully Erosion Area Identification

TABLE A4.3

EXISTING AND ANTICIPATED DEPTHS AND TOP WIDTHS OF GULLIES
USING ESTIMATED VALUES OF D50

Gully Designation	Maximum Depth of Incision (ft)		Top Width at Maximum Depth (ft)		Estimated Age of Gully (years)
	Measured At Present	Anticipated after 50 years	Measured At Present	Anticipated after 50 years	
DG-1	7.5	10.7	19	19 *	70
DG-2	6.5	13.3	19	22 *	38
MG-1	6.0	23.3	19	21	13.5
MG-2	4.0	10.0	5	17	25
GE-1	5.0	29.1	20	26	8
GE-2	7.5	30.0 **	24	41	2.4
GE-3	4.0	14.7	10	21	14
GE-4	3.5	10.6	8	20	19
GE-5	4.0	7.1	6	12	44
GS-1	5.5	22.7	9	23	12

* Estimated values plus the standard error of estimate

** An unrealistically large value of 137.5 ft was obtained using the empirical equations. It is anticipated that rock may be encountered at a depth of about 30 ft whereafter gully erosion may cease. Therefore, a value of 30 ft has been used for Dmax.

TABLE A4.4

APPROXIMATE VOLUMES OF GULLY EROSION

Gully Designation	Erosion Under Existing Conditions (cft)*	Anticipated Erosion After 50 Years From the Present (cft)*	Additional Erosion Over and Above the Existing Condition (cft)*
DG-1	1,496	2,568	1,072
DG-2	1,894	5,813	3,919
MG-1	4,845	23,439	21,594
MG-2	273	3,003	2,730
GE-1	2,533	31,323	28,790
GE-2	22,680	167,280 **	144,600 **
GE-3	547	6,421	5,874
GE-4	266	3,017	2,751
GE-5	196	872	676
GS-1	998	16,516	15,518

* cft = cubic feet

** The empirical equations result in unrealistically high erosion for this gully. The volumes of erosion shown pertain to a maximum gully depth of 30 feet. It is anticipated that rock may be encountered at this depth. Thereafter gully erosion may cease.

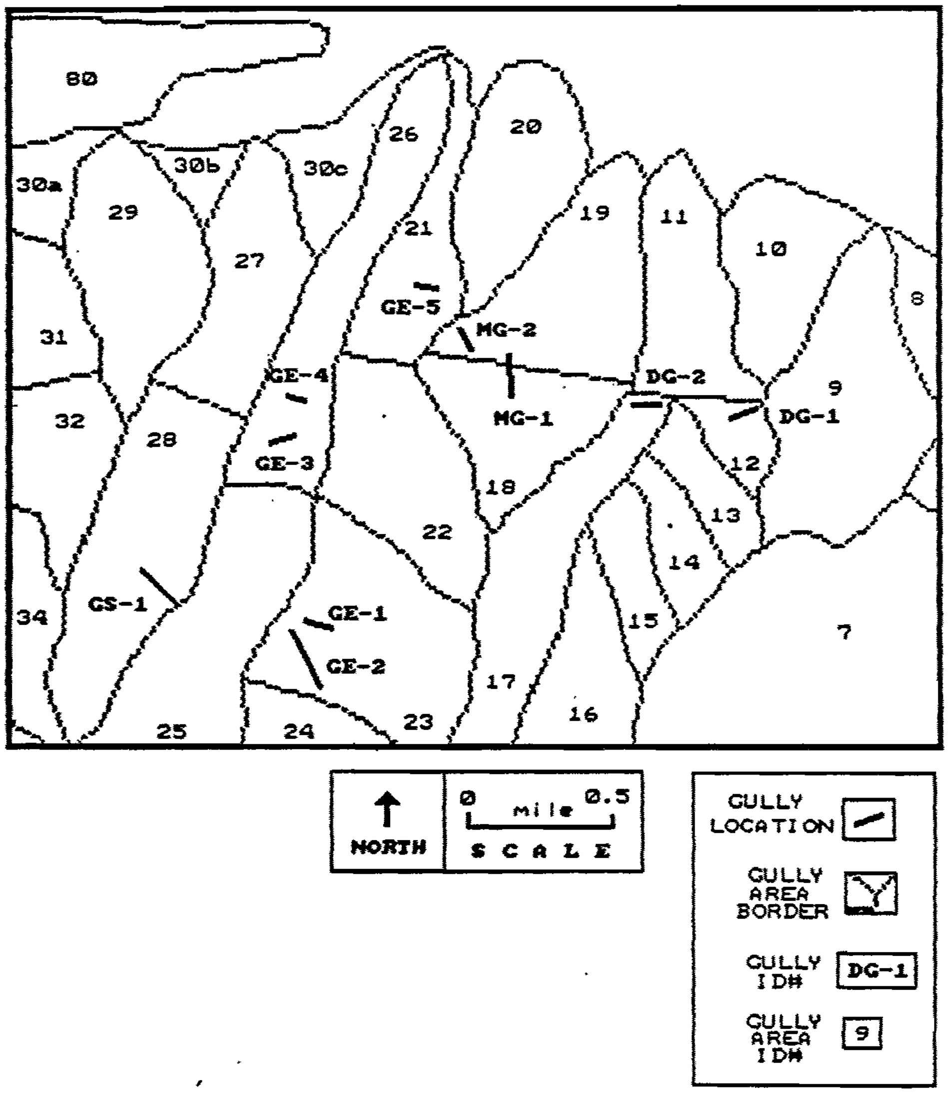


Figure A4.7- Location of Gullies Evaluated by Dames & Moore, 1990

Appendix A5

Material referenced in Section 5

Table A5.1
Market Basket Intakes (mg/kg/day) for Historical Scenario[a]

		Intake by Chemical, mg/kg/day							
Year	Age, yr	Sb	As	Cd	Cu	Pb	Hg	Zn	Weight
1971-77	0-6	5.6×10^{-4}	1.8×10^{-3}	1.4×10^{-3}	-[b]	4.0×10^{-3}	6.7×10^{-5}	1.0×10^{-3}	6
1978-84	7-13	3.2×10^{-4}	1.1×10^{-3}	8.2×10^{-4}	-	2.3×10^{-3}	5.5×10^{-5}	6.1×10^{-4}	7
1985-87	14-16	8.1×10^{-5}	4.4×10^{-4}	2.3×10^{-4}	-	6.1×10^{-4}	4.4×10^{-5}	2.2×10^{-4}	3
1988-95	17-24	7.4×10^{-5}	5.0×10^{-4}	2.1×10^{-4}	-	5.7×10^{-4}	4.7×10^{-5}	2.1×10^{-4}	8
1996-01	25-30	6.9×10^{-5}	5.6×10^{-4}	1.9×10^{-4}	-	5.2×10^{-4}	5.0×10^{-5}	1.9×10^{-4}	6
2002-30	31-59	6.7×10^{-5}	5.6×10^{-4}	1.8×10^{-4}	-	5.1×10^{-4}	4.9×10^{-5}	1.7×10^{-4}	29
2031-41	60-70	6.6×10^{-5}	5.6×10^{-4}	1.6×10^{-4}	-	4.8×10^{-4}	4.8×10^{-5}	1.5×10^{-4}	11
Time Weighted Average Intake		1.4×10^{-4}	7.0×10^{-4}	3.5×10^{-4}	-	9.9×10^{-4}	5.0×10^{-5}	2.9×10^{-4}	70

[a] Values do not include drinking water or beverage intakes.
[b] - No data available.

Table A5.2
Market Basket Intakes (mg/kg/day) for Current Scenario[a]

Year	Age, yr	Intake by Chemical, mg/kg/day Sb	As	Cd	Cu	Pb	Hg	Zn	Weight
1983	1	5.1×10^{-4}	5.4×10^{-4}	4.7×10^{-4}	5.2×10^{-5}	1.9×10^{-3}	5.4×10^{-5}	5.8×10^{-4}	1
1984	2	3.5×10^{-4}	9.4×10^{-4}	5.6×10^{-4}	4.5×10^{-5}	1.8×10^{-3}	1.0×10^{-4}	5.7×10^{-4}	1
1985-95	3-13	5.8×10^{-5}	6.9×10^{-4}	3.9×10^{-4}	3.1×10^{-5}	1.2×10^{-3}	7.2×10^{-5}	3.9×10^{-4}	11
1996-98	14-16	8.1×10^{-5}	4.4×10^{-4}	2.3×10^{-4}	1.7×10^{-5}	6.1×10^{-4}	4.4×10^{-5}	2.2×10^{-4}	3
1999-06	17-24	7.4×10^{-5}	5.0×10^{-4}	2.1×10^{-4}	1.7×10^{-5}	5.7×10^{-4}	4.7×10^{-5}	2.1×10^{-4}	8
2007-12	25-30	6.9×10^{-5}	5.6×10^{-4}	1.9×10^{-4}	1.6×10^{-5}	5.2×10^{-4}	5.0×10^{-5}	1.9×10^{-4}	6
2013-41	31-59	6.7×10^{-5}	5.6×10^{-4}	1.8×10^{-4}	1.5×10^{-5}	5.1×10^{-4}	4.9×10^{-5}	1.7×10^{-4}	29
2042-52	60-70	6.6×10^{-5}	5.6×10^{-4}	1.6×10^{-4}	1.4×10^{-5}	4.8×10^{-4}	4.8×10^{-5}	1.5×10^{-4}	11
Time Weighted Average Intake		7.7×10^{-5}	5.7×10^{-4}	2.3×10^{-4}	1.9×10^{-5}	6.7×10^{-4}	5.2×10^{-5}	2.2×10^{-4}	70

[a] Values do not include drinking water or beverage intakes.

Table A5.3
Estimated Daily Intakes (ug/day) from Market Basket Food*
1982-1984

Age, yr	Intake by Chemical, ug/day						
	Sb[a]	As[b]	Cd[b]	Cu[c]	Pb[b]	Hg[b]	Zn[c]
1	4.6	4.9	4.2	0.47	16.7	0.49	5.2
2	4.6	12.2	7.3	0.58	23	1.3	7.4
14-16	4.6	23-27.7[d]	10.6-15.4	0.77-1.2	28.7-41.3	2.4-2.6	9.9-15.6
25-30	4.6	31-45.3	10.6-15.4	0.93-1.2	29.6-40.9	2.9-3.9	9.6-16.2
60-65	4.6	35.2-43.8	9.6-12.7	0.86-1.2	30.4-37.6	3.1-3.6	8.5-12.6

Sources: (a) Iyengard, 1987.
(b) USFDA, 1988.
(c) USFDA, 1986b.

(d) Where a range is given, the lower value is for females and the higher for males.

* Values do not include drinking water or beverage intakes.

Table A5.4
Metals Concentrations (ppm, wet wt.) in Local Garden Vegetables versus Market Basket Produce
Mean/Maximum

		Cd	Pb	Zn
Root Crops (Beets, Carrots):				
Areas 1 & 2 (1983)		1.5/4.2	4.5/24.6	29.2/133
Area 3 (1983)		0.45/1.3	2.2/9.2	14.7/61.9
National Survey	(1979-80)	-0.003/0.07	-0.03/0.11	-2.7/5.2
	(1980-82)	0.02/0.03	0.04/0.38	2.1/2.9
	(1982-84)	0.03/0.15	0.04/0.17	2.8/5.1
Leafy Vegetables (Lettuce, Spinach):				
Areas 1 & 2 (1983)		1.8/6.6	6.1/15.5	27.5/75.1
Area 3 (1983)		1.2/2.8	3.5/8.3	27.7/55.8
National Survey	(1979-80)	0.01/0.02	0.1/0.17	5.8/11
	(1980-82)	0.03/0.06	0.02/0.07	2.3/3.6
	(1982-84)	0.05/0.49	0.03/0.14	2.9/6.4

Sources: USFDA, 1985, 1986a-b, and 1988.
PHD et al., 1986.

BOIT793/009.51/jms

Table A5.5
Metals Concentrations (ppm, wet wt.) in
Tap Water and Fish
Mean/Maximum

	Cd	Pb	Zn
Columbia River (whole fish)[a]	0.1 / 0.3	0.34 / 2.6	--
All National Pesticide Monitoring Stations (1976/77)[a]	0.11 / --	0.34 / --	--
Lake Coeur d'Alene (1985)[a]	0.13 / 0.37	0.80 / 3.3	--
Drinking Water (tap; IDHW 1976-1985)	<2 μg/L	<10 μg/L	2,242 μg/L

Source: ATSDR, 1989.

BOIT793/010.51/tlm

TABLE A5.6

PRELIMINARY GROUNDWATER DISSOLVED METALS CONCENTRATIONS

	Groundwater Mean Concentrations ($\mu g/L$) Sb	As	Cd	Pb	Hg	Zn
Pinehurst	(no representative data available)					
Kellogg (wells: BH-2, DH-25, GR-44, GR-52)	< 50	5	38	81	< 0.2	8,380
Smelterville (wells: GPT-1, GPT-2, GR-1, GR-28, GR-32)	< 50	14	247	175	< 0.2	11,000
Background: Northern Idaho (Parliman et al., 1980)	-	1.5	6	8.5	~0	810

Table A5.7
High Wind Event Air Metals Concentrations ($\mu g/m^3$), 1987
(for all days between 7/1/87 and 10/30/87 [10 am-6 pm] when TSP ≥ 150 $\mu g/m^3$)
Mean/Maximum

	% days, TSP ≥ 150 $\mu g/m^3$	TSP	As	Cd	Cu	Pb	Sb	Zn
Smelterville (1 sampler)	7	203/822	0.020/0.089	0.015/0.062	0.17/0.49	1.00/8.59	0.05/0.08	2.45/7.42
Kellogg (5 samplers)	4-8	147-181/690-904	0.017-0.087/0.131-0.625	0.011-0.044/0.058-0.237	0.07-0.20/0.17-0.76	0.38-2.40/2.87-15.46	0.03-0.14/0.05-0.40	2.10-3.44/6.15-14.09
Pinehurst (1 sampler)	11	200/589	0.008/0.014	0.002/0.002	0.20/0.44	0.22/1.71	0.02/0.02	1.50/6.79

BOIT793/018.51/jms

Appendix A6

Material referenced in Section 6

Table A6.1
Percentile Distributions for Childhood (ages ≤ 9 yrs.)
Blood Lead Levels at Bunker Hill

	Percentile Distributions						
Blood Lead Level, μg/dl	1974 (n=572)	1975 (n=699)	1980[a] (n=450)	1983 (n=364)	1988 (n=228)	1989 (n=275)	1990 (n = 362)
1				0.5			0.3
3						0.4	
4				0.8	18.4	12.0	18.8
5				3.0	24.6	15.3	28.4
6				5.8	34.6	23.3	37.8
7			0.2	9.9	42.5	31.6	47.2
8			0.4	14.0	48.2	38.2	56.9
9				19.5	54.8	44.0	63.0
10				26.4	65.8	50.5	69.9
11	0.2		1.1	33.2	73.2	56.0	75.1
12		0.1	2.2	39.8	76.3	64.4	81.2
13		0.3	3.8	44.8	80.7	68.4	85.1
14			6.0	50.8	84.6	74.2	88.7
15		0.4	9.1	56.6	87.7	77.1	91.2
16		1.1	12.7	60.4	89.9	81.5	92.8
17		1.4	15.1	64.6	92.1	83.3	94.5
18		2.9	19.6	70.1	94.7	89.1	95.9
19	0.3	3.3	22.9	73.6	95.6	90.5	96.7
20	1.0	4.4	27.8	78.3		94.5	97.8
21	1.2	5.3	32.0	80.5	96.1	95.6	98.3
22	1.6	6.9	37.1	81.9		96.4	98.9
23	1.9	8.9	42.2	85.4	96.5	97.1	99.4
24	3.0	11.0	46.2	86.3	96.9		
25	3.7	13.9	52.2	88.2	97.4	97.5	99.7
26	5.1	16.6	54.7	90.1	97.8	97.8	
27	7.3	18.0	59.3	91.2			
28	9.1	20.6	61.8	92.0	98.2	98.2	
29	11.2	23.3	66.0	93.1		98.5	
30	12.6	26.3	70.7	94.0		98.9	100.
31	15.2	30.5	75.1	95.3			
32	17.5	33.9	77.1	96.2			
33	19.1	37.8	79.8	96.4			
34	21.9	40.1	81.8	96.7			
35	24.3	43.8	83.6	97.3			
36	25.9	46.1	85.3	97.8			
37	30.1	48.6	87.6	98.6	98.7		
38	32.0	51.8	88.4			99.3	
39	34.3	55.5	90.0		99.1		
40	36.5	58.4	90.9	99.2		99.6	
41	38.6	61.2	92.0		99.6	100.	
42	41.6	64.7	93.1				
43	44.4	67.5	95.1	99.5			
44	46.9	69.7	95.8				
45	48.4	72.8		100.			
46	50.7	75.5	96.4				
47	52.6	77.8					
48	55.2	79.4	97.1				
49	56.1	80.7	97.6				
50	57.9	82.5	97.8				
51	59.6	83.5					
52	61.0	85.6	98.2				
53	63.5	86.7					
54	65.6	88.1					
55	67.1	90.1			100.		
56	68.7	91.3	98.4				
57	70.3	91.8	99.1				
58	71.9	93.1	99.8				
59	72.7	93.7					
60	74.1	93.8					
61	76.2	94.7					

Table A6.1 (Continued)
Percentile Distributions for Childhood (ages ≤ 9 yrs.)
Blood Lead Levels at Bunker Hill

Blood Lead Level, μg/dl	Percentile Distributions 1974 (n=572)	1975 (n=699)	1980[a] (n=450)	1983 (n=364)	1988 (n=228)	1989 (n=275)	1990 (n = 362)
62	77.4	95.0					
63	79.0	95.3	100.				
64	80.1	96.1					
65	81.3	96.6					
66	82.2	96.7					
67	82.9	97.3					
68	84.3	97.4					
69	85.1	98.3					
70	86.5	98.6					
71	88.3	98.9					
72	89.0	99.0					
73	89.9	99.3					
74	90.6						
75	90.7						
76	91.3	99.4					
77	91.8						
78		99.6					
79	92.7						
80	93.5						
82	93.9						
83	94.2						
84	94.4						
85	94.8	99.9					
86	95.3						
88	95.6						
89	95.8						
90	96.0						
91	96.2						
92	96.5						
93	96.7						
94	96.9						
95	97.0						
96	97.2						
97	97.4						
98	97.7						
100	97.9						
102	98.3						
107	98.6						
109	98.8						
111	99.0						
114	99.1						
120	99.3						
129	99.5						
134	99.7						
136		100.					
143	99.8						
164	100.						

Source: IDHW Program Files
(a) For children ages ≤ 12 years.

BOIT774/012.51-pe/tlm

Figure A6.1

1974 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 9 Years of Age

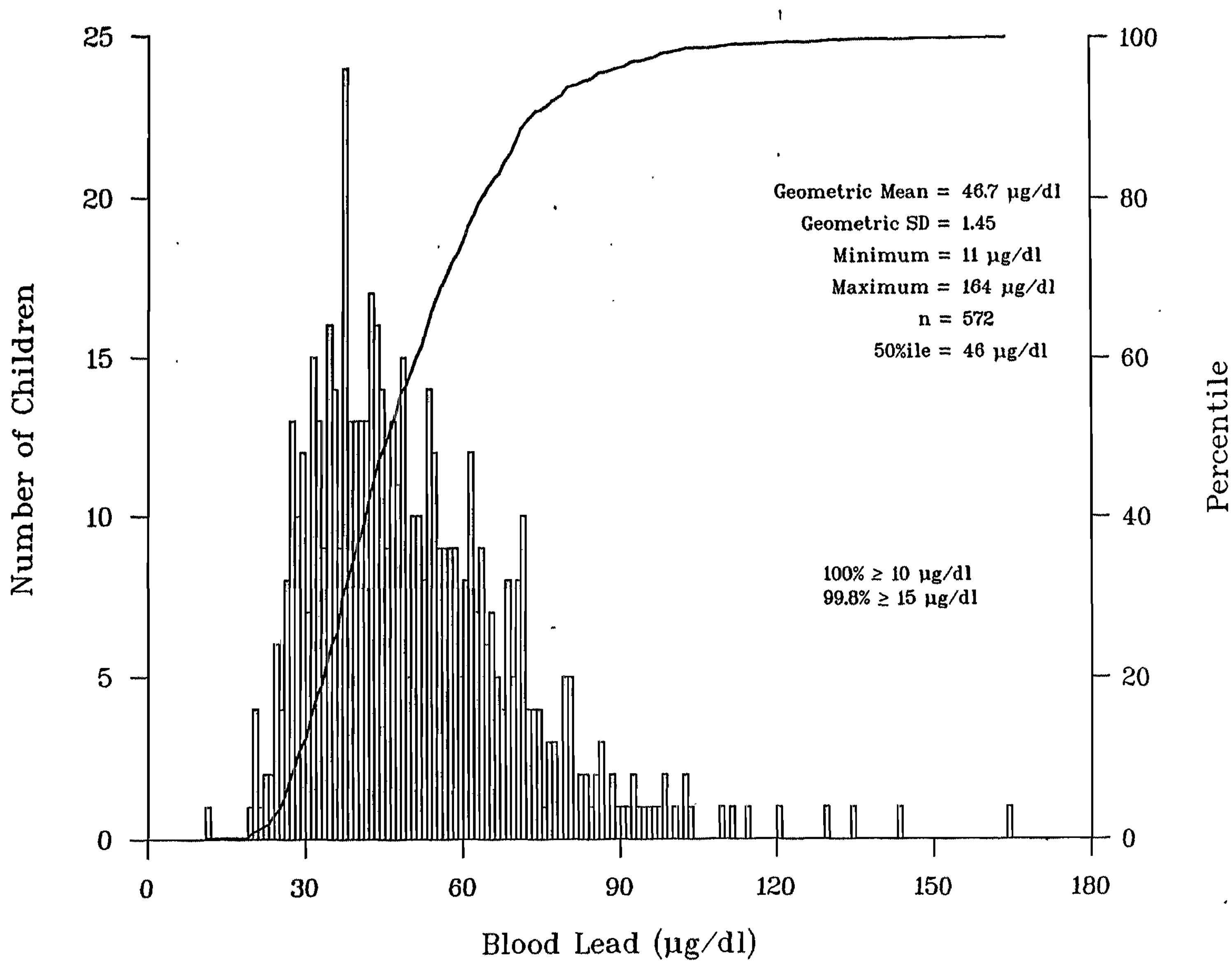


Figure A6.2

1975 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 10 Years of Age

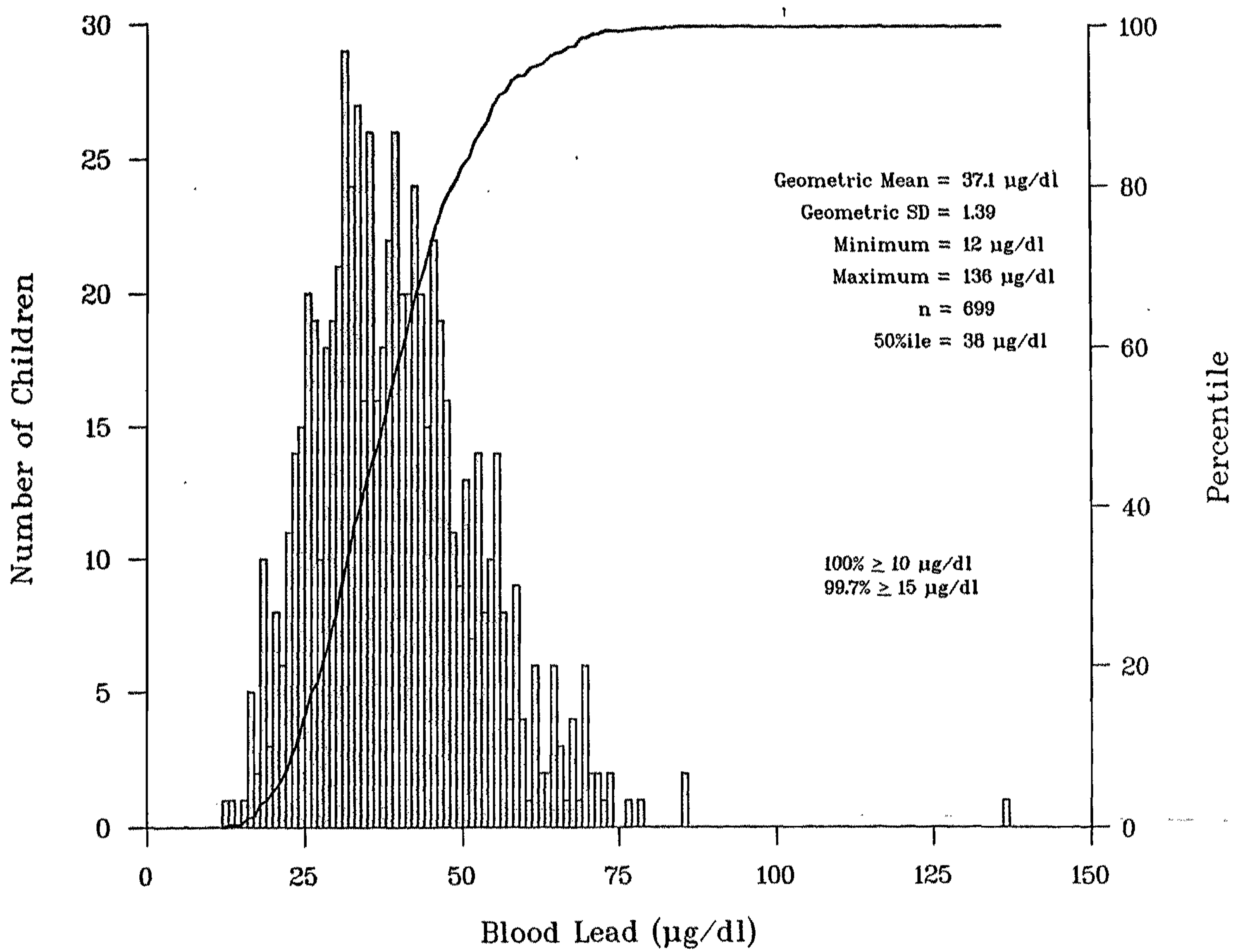


Figure A6.3

1980 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 12 Years of Age

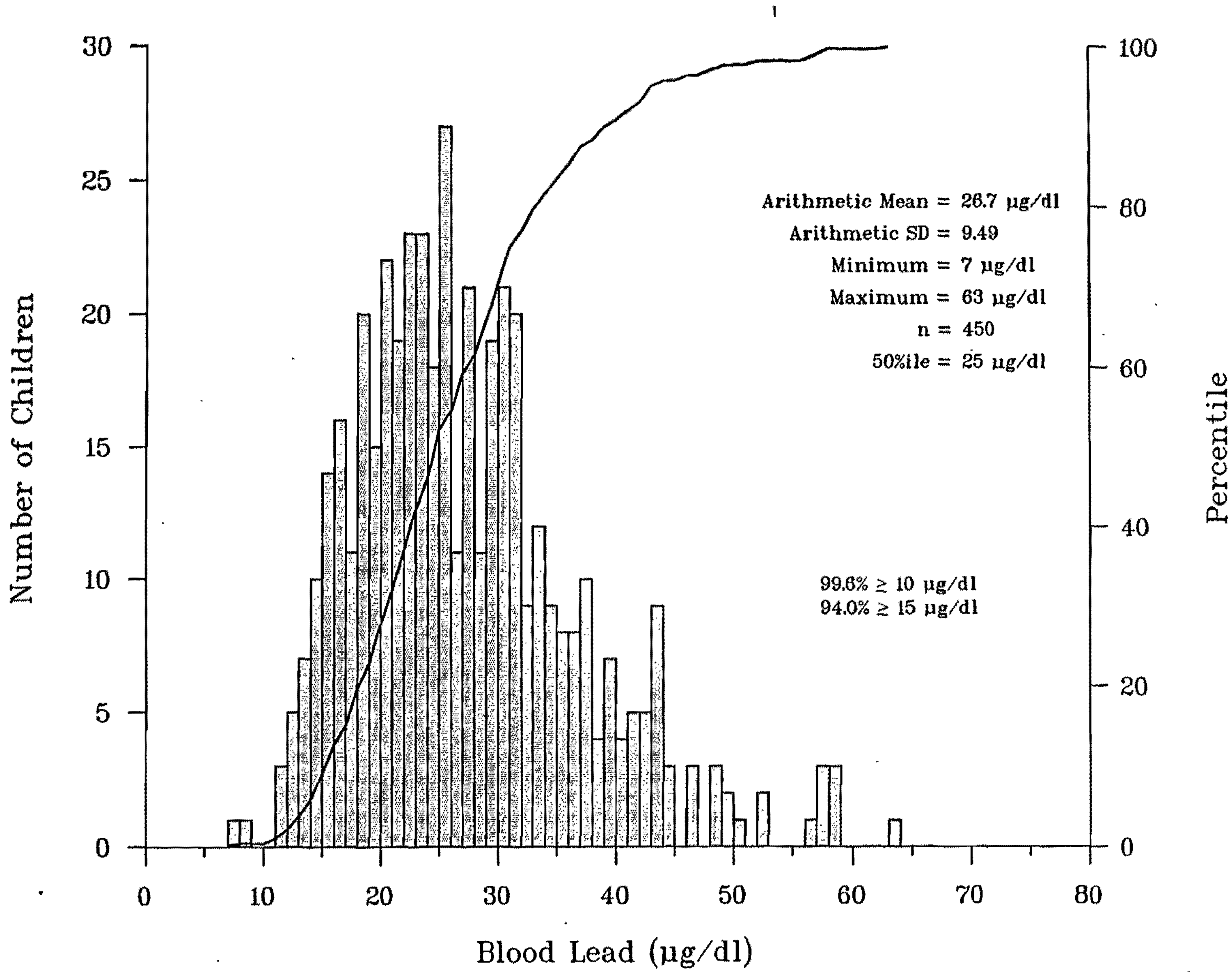


Figure A6.4

1983 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 9 Years of Age

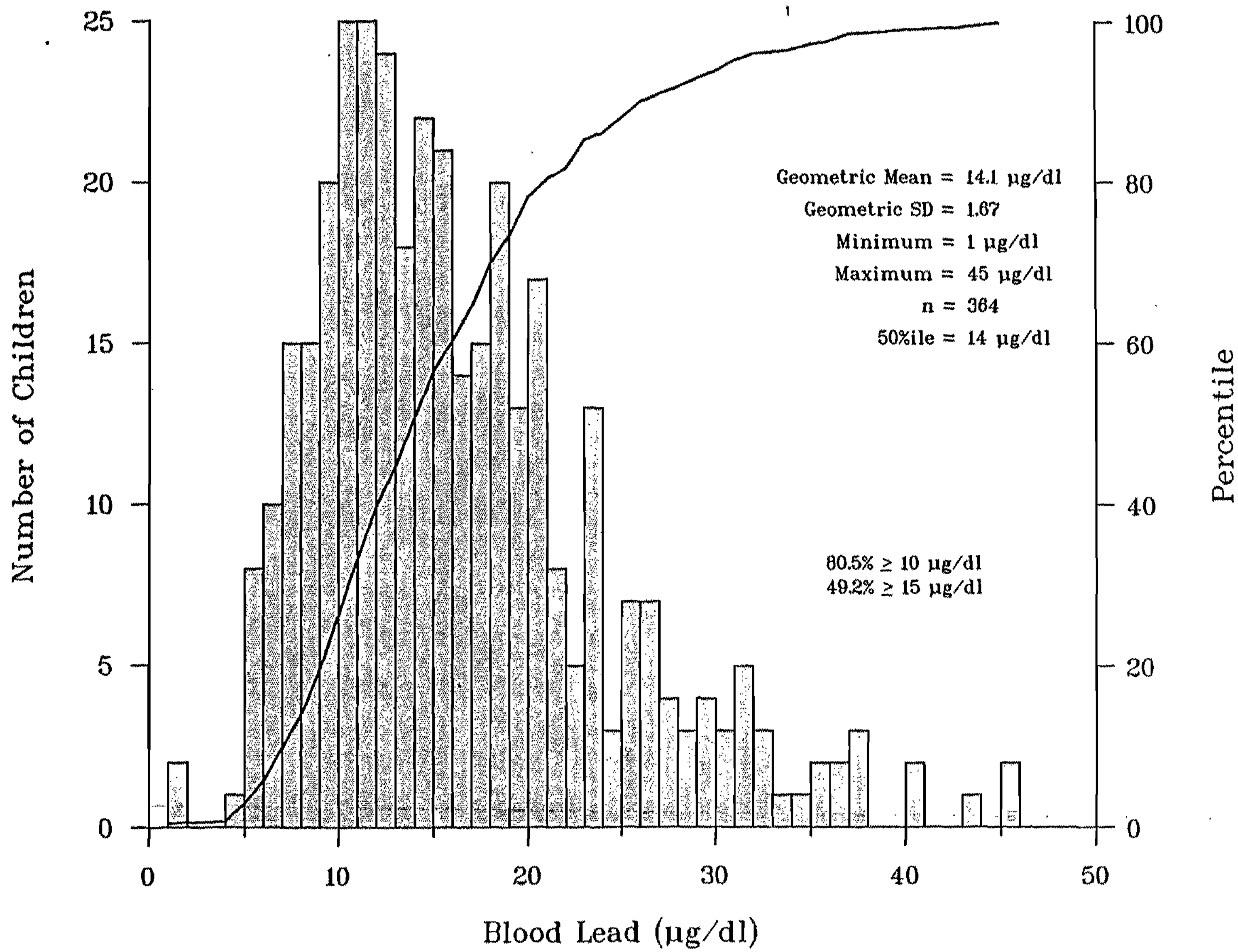


Figure A6.5

1988 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 9 Years of Age

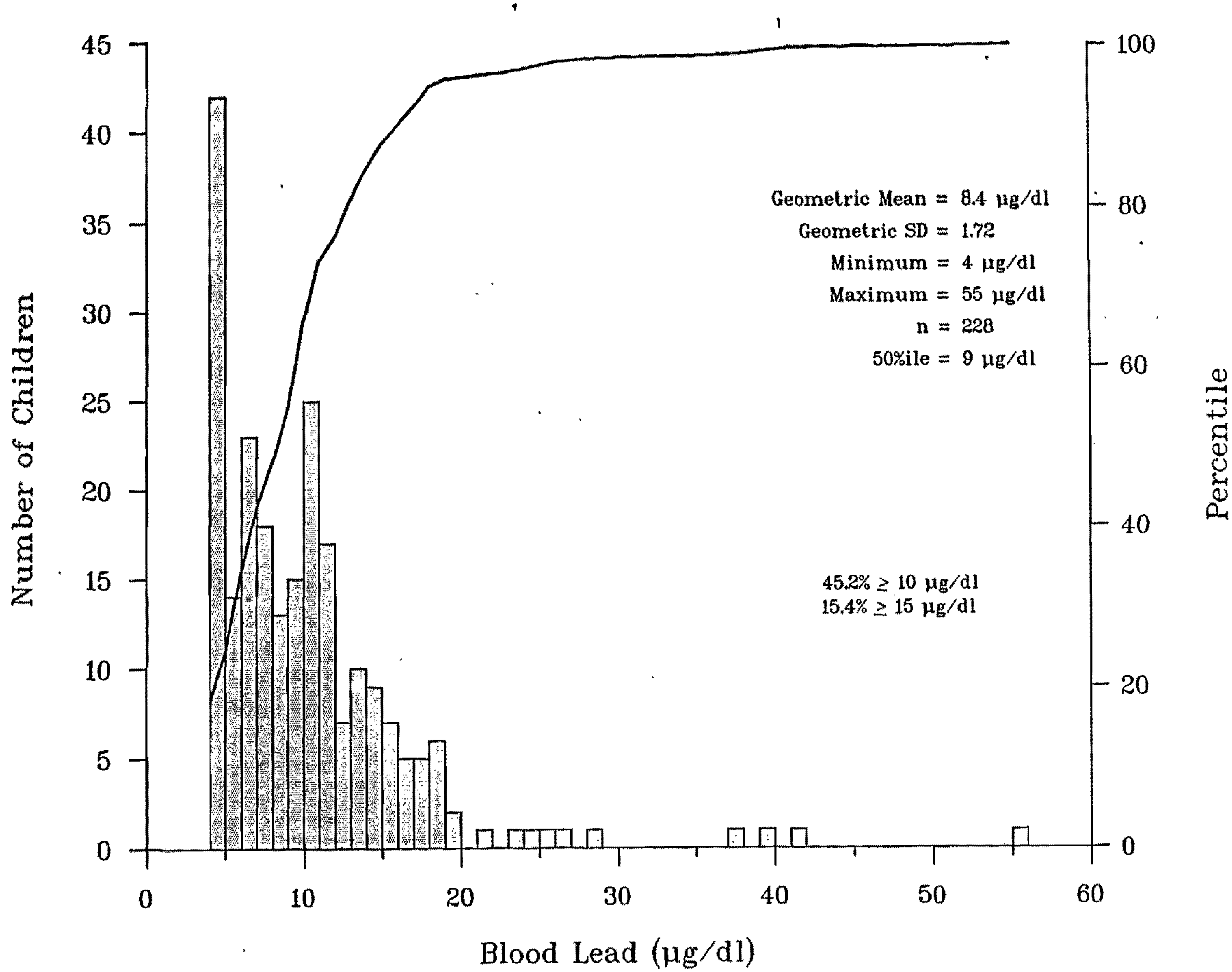


Figure A6.6
1989 Bunker Hill Populated Areas Blood Lead Distribution for Children ≤ 9 Years of Age

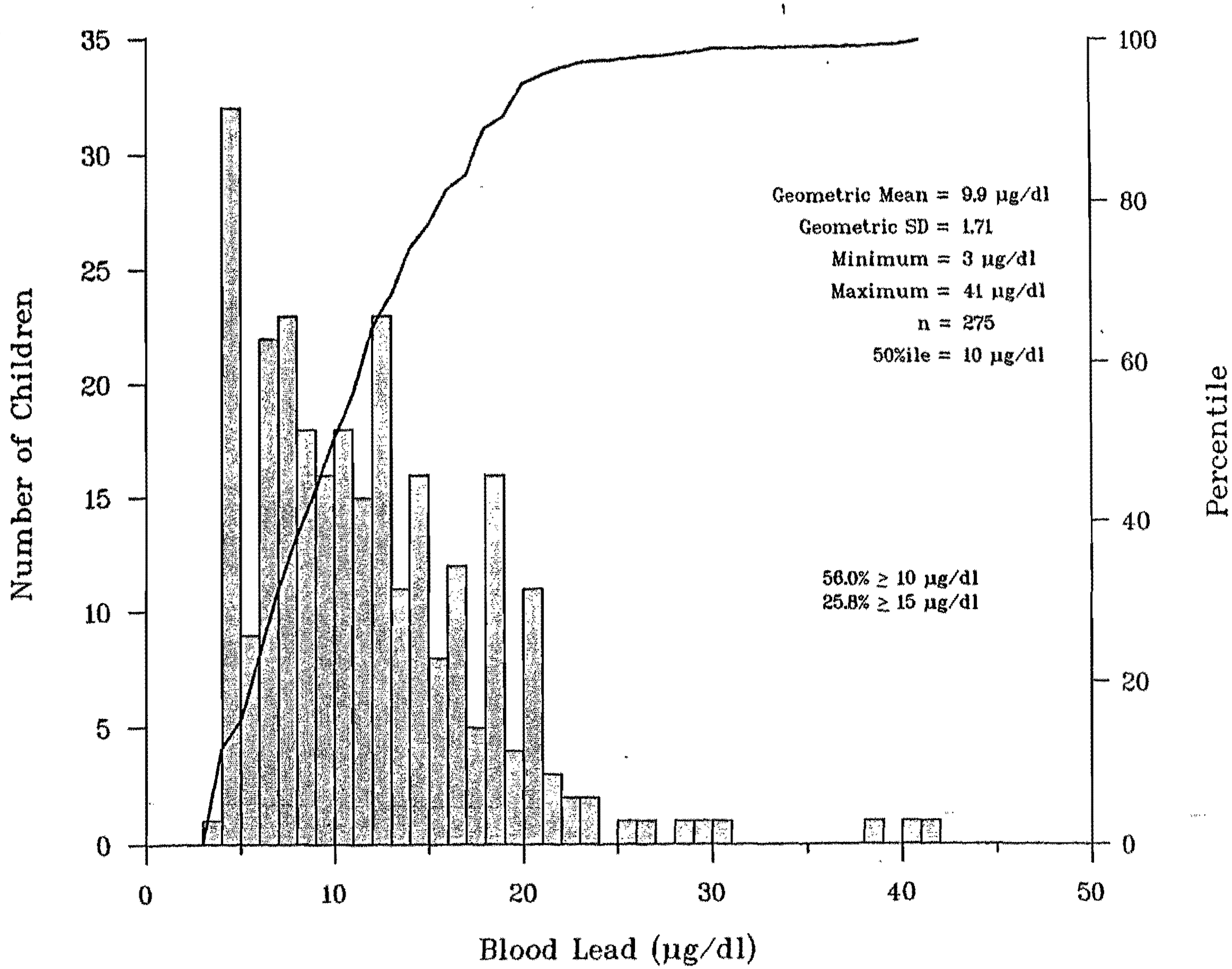
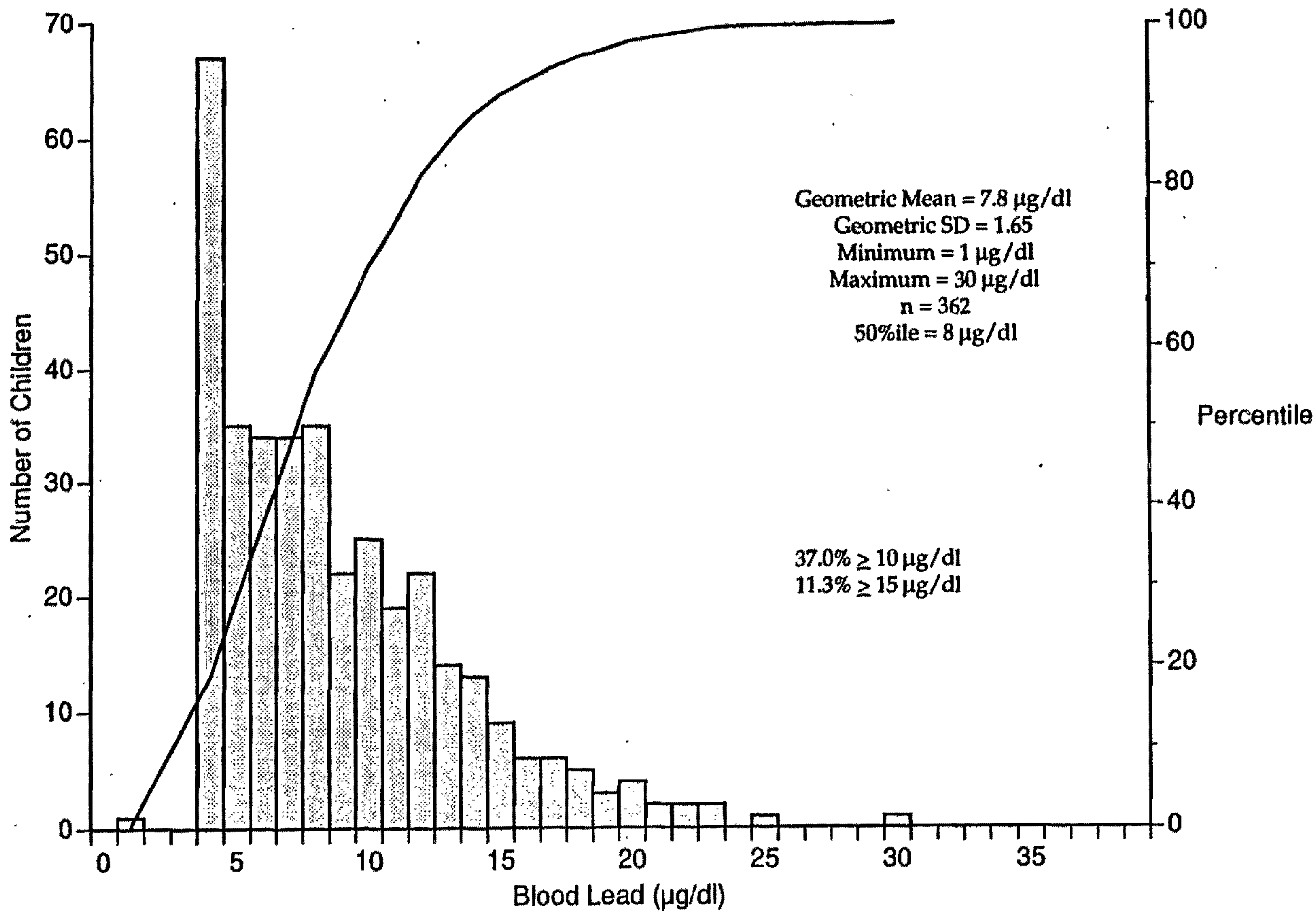


FIGURE A6.7
1990 Bunker Hill Populated Areas Blood Lead
Distribution for Children ≤ 10 Years of Age



Appendix B

Hanson Memo
June 20, 1990

EPTox Characterization of Residential Soils at the Bunker Hill Superfund Site

State of Idaho
DEPARTMENT OF HEALTH AND WELFARE
Division of Environmental Quality

450 W. State Street
Boise, Idaho 83720

CECIL D. ANDRUS
Governor
RICHARD P. DONOVAN
Director

June 20, 1990

MEMORANDUM

TO: File

FROM: Rob Hanson RH

SUBJECT: EPTOX Characterization of Residential Soils at the Bunker Hill Superfund Site

Introduction

Residential soil at the Bunker Hill Superfund Site has been found to be contaminated with heavy metals originating from smelting and mining activity in the Silver Valley. As part of the Removal Action, soils will be removed from residential yards and replaced with uncontaminated soil. The removed soil will need to be disposed in an appropriate repository. However, before a repository can be properly designed, a determination needs to be made relative to the hazardous nature of the soils.

Hazardous waste characteristics are determined pursuant to criteria in the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §6921, as amended, and are specifically identified from analytical results obtained from the extraction procedure toxicity (EPTOX) test 40 CFR Part 261.24. If the soils are found to exhibit specific hazardous waste characteristics and are thereby classified as a hazardous waste, they will need to be disposed in a RCRA Subtitle C landfill. If the soils are not determined to be a characteristic hazardous waste, a less stringent landfill design is required.

Residential soils that will be placed in the repository will be mixed with soils from several different yards. The mixture of soils removed from the properties is considered a "Solid Waste" under RCRA and must be evaluated to determine whether it is a RCRA hazardous waste. Two different sets of soil samples were analyzed for EPTOX metals for the purpose of characterizing the hazardous nature of residential soils at the Bunker Hill Site. The results of these analyses are discussed below.

Discussion

The first sample set was selected to ensure that EPTOX results would represent a conservatively high estimate of any hazardous characteristic of the residential soil. The top 6 inches of 23 soil cores taken during the 1987 soil core sampling program were used for this analysis. The 23 cores were selected from the 40 soil cores collected. Cores with the highest total lead (Pb) levels (based on portable X-ray fluorescence analyses) from Kellogg, Smelterville, Pinehurst, Wardner, and Page were selected for EPTOX characterization. Of the cores selected, eight were collected in Kellogg, six from Smelterville, and three from each of the other three communities. Three samples with total Pb concentrations below 1000 mg kg^{-1} were also analyzed for EPTOX metals.

The arithmetic mean EPTOX Pb value for the 23 samples was 4600 ug L^{-1}. The geometric mean value was 1500 ug L^{-1}. Both concentrations are below the 5000 ug L^{-1} EPTOX critical level. Three individual samples did exceed the 5000 ug Pb L^{-1} concentration. The concentrations for these samples were 8560, 5720, 49,800 ug L^{-1} (Table 1). All other metal analyte (arsenic, barium, cadmium, chromium, mercury, and selenium) concentrations were also below the EPTOX critical levels with many even below instrument detection limits. Further information on soil core analytical results are reported in the Bunker Hill Soil Core Data Summary Report (in draft).

Since the mean Pb values were below the EPTOX critical level, the data indicate that a mixture of residential soils would not be a characteristic hazardous waste. This assumes that thorough mixing occurs during the removal and disposal operation. (A solid waste, as defined in §261.2, is a hazardous waste if it is a mixture of a solid waste and a hazardous waste that is listed in Subpart D solely because it exhibits one or more of the characteristics of hazardous waste identified in Subpart C, *unless the resultant mixture no longer exhibits any characteristic of hazardous waste identified in Subpart C* (40 CFR 261.3(a)(2)(iii))) (emphasis added).

The second sample set consisted of soil samples taken just prior to the 1989 emergency soil removal action. Two composite samples consisting of the 0-6 and 6-12 inch increments from 22 residential yards were taken and analyzed for EPTOX metals. Composites were used to characterize the hazardous nature of mixed residential soil. The Pb analytical result for the 0-6 inch increment was below the detection limit of 500 ug L^{-1}. The Pb concentration for the 6-12 increment was 3500 ug Pb L^{-1}. Results for all other metals were below the EPTOX critical levels and were also below instrument detection limits indicating very low leachable metal concentrations in the soil. These results provide further evidence that the top 0-6 inch layer of residential soil does not exhibit RCRA hazardous waste characteristics. Results also show that the 6-12 inch increment does not exhibit hazardous characteristics.

Conclusion

Analytical results from EPTOX tests show that soil wastes resulting from removal of the top 6 or 12 inches of soil from residential yards at the Bunker Hill Superfund site are not a RCRA characteristic hazardous waste. Therefore, a Subtitle C landfill will not be required to safely dispose of waste soils.

Table 1. EPTOX analytical results for the 23 soil cores taken from Kellogg, Smelterville, Pinehurst, Wardner, and Page.

	Metal Analyte							
Sample	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
	ug L^{-1}							
1	ND	340	15	ND	179	ND	ND	ND
2	ND	276	4	ND	250	ND	ND	ND
3	ND	232	27	ND	4040	ND	ND	ND
4	ND	505	303	ND	4140	ND	ND	ND
5	ND	472	230	ND	4660	ND	ND	ND
6	ND	322	81	ND	3280	ND	ND	ND
7	ND	517	75	ND	1620	ND	ND	ND
8	ND	414	19	ND	566	ND	ND	ND
9	ND	790	192	ND	4040	ND	ND	ND
10	ND	670	163	ND	4600	ND	ND	ND
11	ND	416	28	ND	457	ND	ND	ND
12	ND	626	6	ND	244	ND	ND	ND
13	ND	1310	152	ND	4280	ND	ND	ND
14	ND	962	34	ND	313	ND	ND	ND
15	ND	473	158	ND	3690	ND	ND	ND
16	ND	856	25	ND	161	ND	ND	ND
17	ND	865	72	ND	3830	ND	ND	ND
18	ND	759	138	ND	8560	ND	ND	ND
19	ND	484	125	ND	3820	ND	ND	ND
20	ND	915	31	ND	156	ND	ND	ND
21	ND	213	12	ND	82	ND	ND	ND
22	ND	579	85	ND	5720	ND	ND	ND
23	ND	160	234	ND	49800	ND	ND	ND

ND Concentration below the instrument detection limit

EPTOX Critical Levels (ug L^{-1})

As, Cr, Pb, Ag	5000
Ba	100,000
Cd, Se	1000
Hg	200

Appendix C

Evaluation and Testing of the Integrated Uptake/Biokinetic Dose-Response Model for Lead

Appendix C. Evaluation and Testing of the Integrated Uptake/Biokinetic Dose-Response Model For Lead

The integrated uptake/biokinetic (IU/BK) dose-response model for lead has been used by the U.S. EPA Office of Air Quality Planning and Standards (OAQPS) to determine the National Ambient Air Quality Standard (NAAQS) for lead, and is being considered by the EPA Environmental Criteria and Assessment Office (ECAO) as a method for determining site-specific cleanup levels for lead contaminated soils and dusts.

The model consists of two parts; an integrated uptake portion and a physiological response (biokinetic) portion. Total lead uptakes are predicted for children by integrating (summing) uptakes associated with various exposure pathways. Critical exposure pathways for children include:

- ingestion of contaminated residential soils and dusts, including interior house dusts,
- consumption of contaminated food and water, and
- inhalation of contaminated air particulate matter.

Age-specific intake factors are applied to each of the exposure pathways for estimating media and consequent lead intakes. Lead uptakes (absorbed lead) are then estimated by multiplying each of the media-specific intakes by an age-specific absorption/deposition coefficient.

$$PbUT_{(total)} = PbUT_{(air)} + PbUT_{(diet)} + PbUT_{(soil)} + PbUT_{(dust)}$$

where: $PbUT_m$ = lead uptake from media m

$= AC_{m,i} \times PbIT_m$

$AC_{m,i}$ = age-specific physiologic absorption coefficient for each medium m

$PbIT_m$ = lead intake for each medium m

= (media lead concentration) x (intake factor)

The biokinetic, or physiologic response, portion of the model predicts an age-specific mean blood lead concentration from total lead uptake using a linear relationship between absorbed lead and blood lead at levels of uptake from 10 to 100 μg Pb/day. The linear response coefficients are age dependent and expressed in terms of age-specific reciprocal clearance rates or blood lead response coefficients (Harley and Kneip, 1985).

$$Bl\text{-}Pb_i = PbUT_{(total)} \times CR^{-1}$$

where age-specific reciprocal clearance rates (CR^{-1}) are:

age (yr):	1	2	3	4	5	6	7	8	9	10
CR^{-1} (day/dl):	0.297	0.404	0.366	0.350	0.363	0.345	0.325	0.248	0.232	0.260

Linearity and greatest predictive power of the biokinetic portion of the model is at blood lead levels less than 30-40 μg/dl; progressively greater uptakes are required to yield equal and successive incremental increases in blood lead levels above 30-40 μg/dl. This relationship of reduced slopes between blood lead level and intake at higher blood lead levels may be due to nonlinear renal clearance, distributional non-linearities due to differences in lead binding sites in different tissues, and/or to a sizeable pool of mobile lead in bone maintained independently of uptake (U.S. EPA, 1989e).

Total population distributions are described by a log normal distribution curve defined by a mean blood lead response, for all ages of concern, and an observed or selected geometric standard deviation (GSD). As a result, the model is able to predict what percentage of children have blood lead levels (Bl-Pb) above or below a chosen cutoff value.

The model is flexible and allows the use of site-specific input data as well as default values for critical input parameters. A test of model sensitivity to input parameters has shown that in most environments, including Bunker Hill, where residual lead contamination is associated with soils and dusts, the critical input parameters are dietary lead intake, soil and dust ingestion rate, gastrointestinal absorption of lead, and the variance in blood lead response (in terms of the geometric standard deviation about the mean blood lead) (Hoffnagle 1988; U.S. EPA,1990e). Site-specific epidemiological data is applied here to test and validate critical input parameters to the IU/BK dose-response model for lead.

Assumptions or Default Values Used In the U.S. EPA/OAQPS Integrated Uptake/Biokinetic Dose-Response Lead Model

Age (yr):	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Time spent outdoors (hr/day):	1-2	1-3	2-4	2-5	2-5	2-5	2-5
Ventilation rate (m^3/day):	2-3	3-5	4-5	4-5	5-7	5-7	6-8
Average GI Absorption Rate for Dietary Lead(%):	42-53	42-53	30-40	30-40	30-40	30-40	18-24
Dirt Ingestion (mg/day):	0-85	80-135	80-135	80-135	70-100	60-90	55-85

Indoor : Outdoor Air Lead = 0.3 - 0.8
Time spent outdoors by children is approximately 25% of waking hours.
GI Absorption of Lead in Soil/Dust = 25-30%
Airborne Lead Absorption/Deposition = 42%

The following analysis is accomplished to determine and evaluate site-specific values for use in the IU/BK dose-response model in order to accurately reflect site population characteristics and behaviors, and to permit accurate predictions of population response to environmental lead levels in order to evaluate with confidence selected remedial alternatives and cleanup goals.

Total mean lead uptakes for the childhood population can be determined using age-specific mean blood lead concentrations and age-specific lead clearance rates.

$$PbUT_{(total)} = Bl\text{-}Pb/(\text{Biokinetic Response Coefficient}) = Bl\text{-}Pb \times CR$$

A comparison of mean blood lead concentrations for each age category (from Figures C1 through C6) to biokinetic response coefficients (biokinetic response coefficient = reciprocal clearance rate (CR^{-1})) shows a high degree of correlation. As an example, Figure C7

Figure C1

1974 Blood Lead Summary Statistics by Age for Children ≤ 9 Years

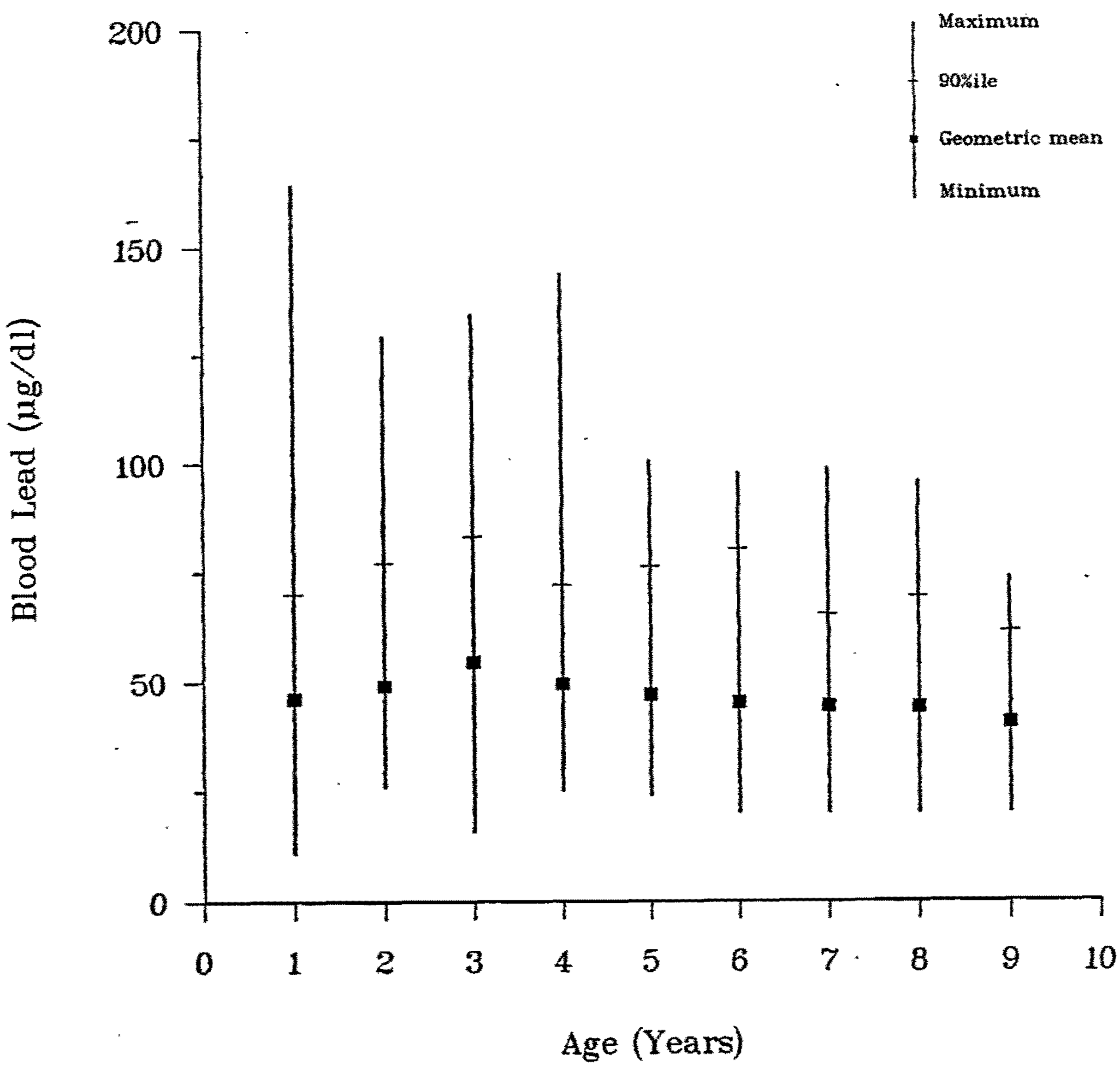


Figure C2

1975 Blood Lead Summary Statistics by Age for Children ≤ 10 Years

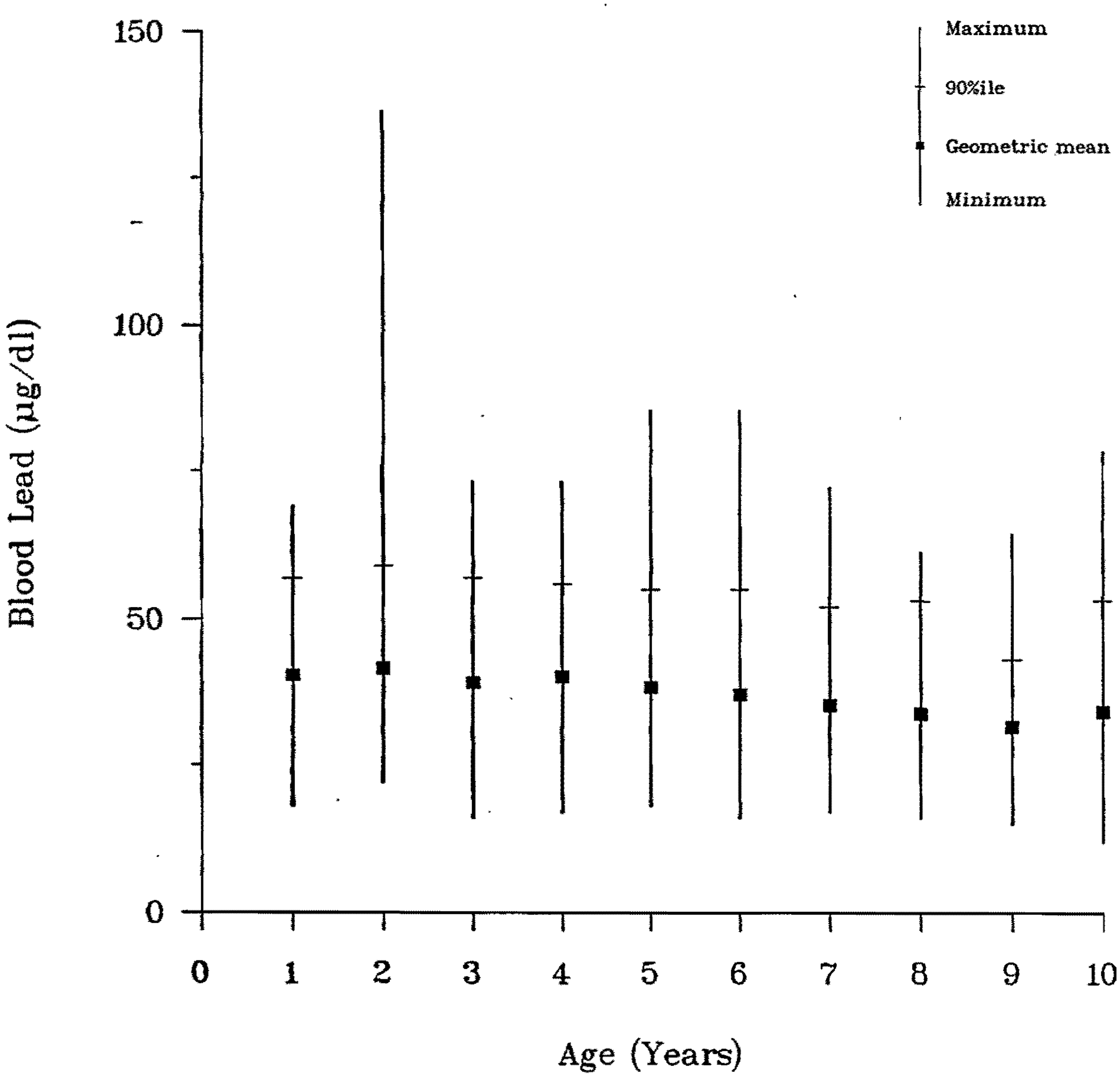
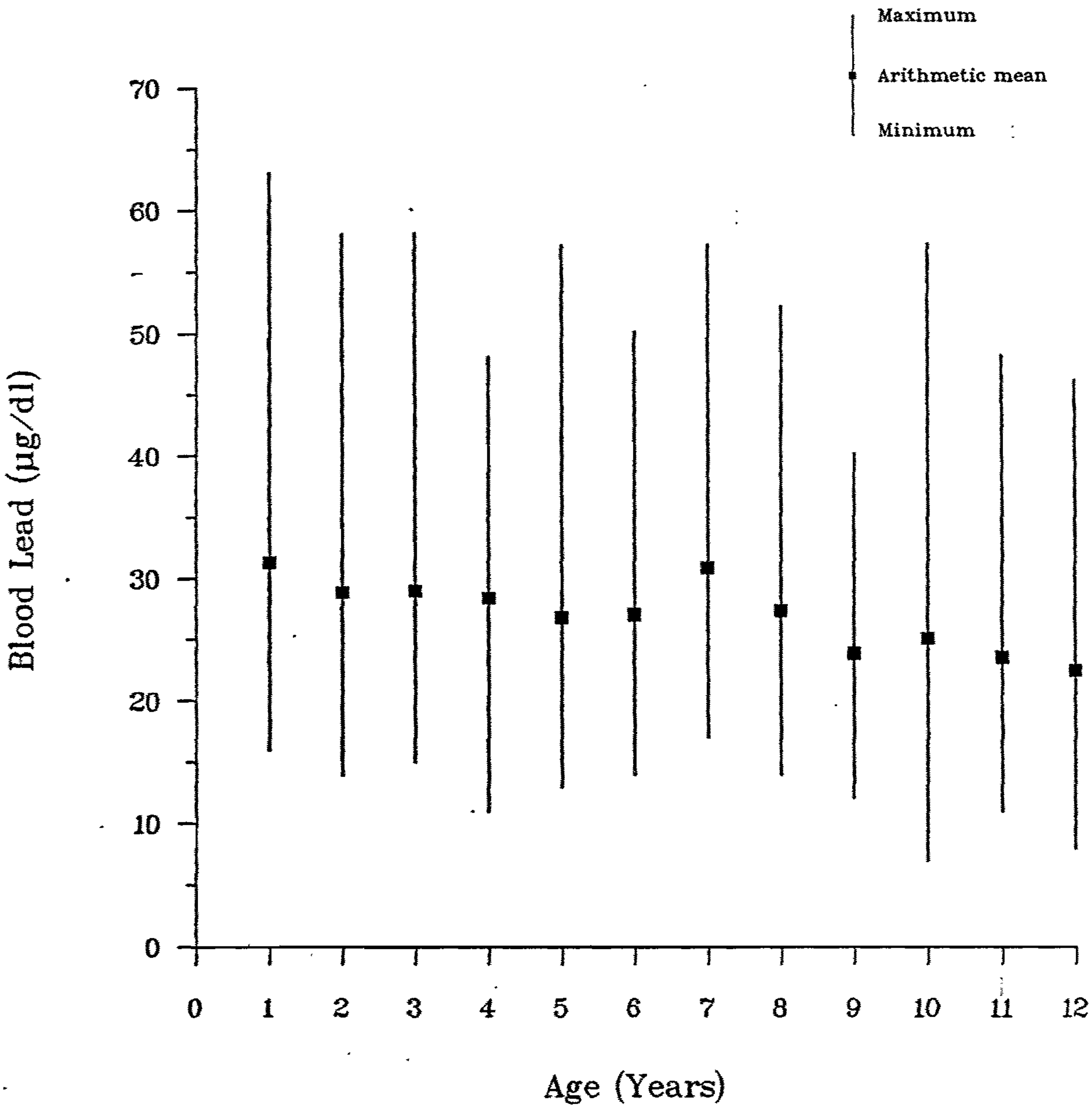


Figure C3

1980 Blood Lead Summary Statistics* by Age for Children ≤ 12 Years



* Percentile distributions not available by age.

Figure C6

1989 Blood Lead Summary Statistics by Age for Children ≤ 9 Years

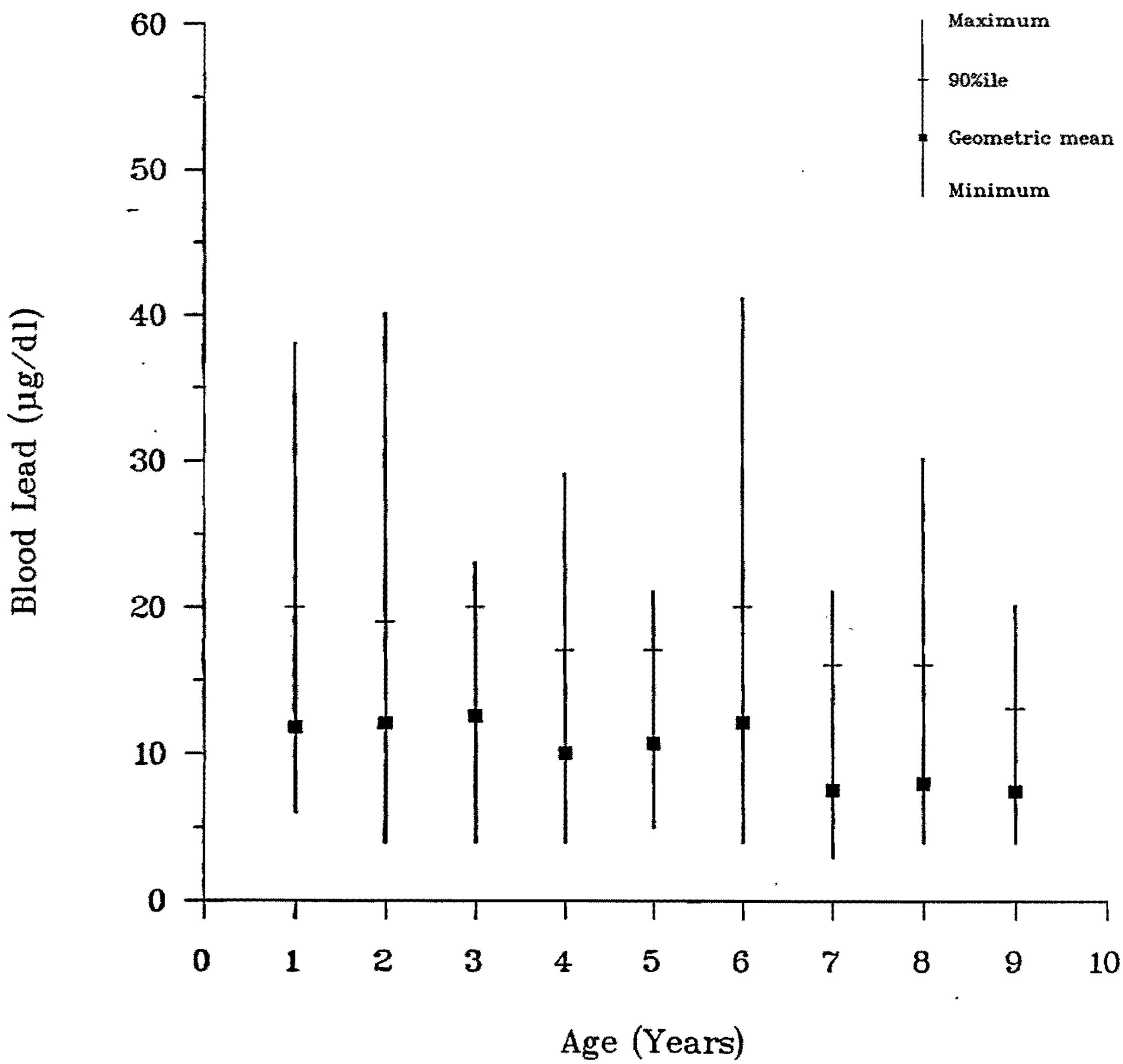
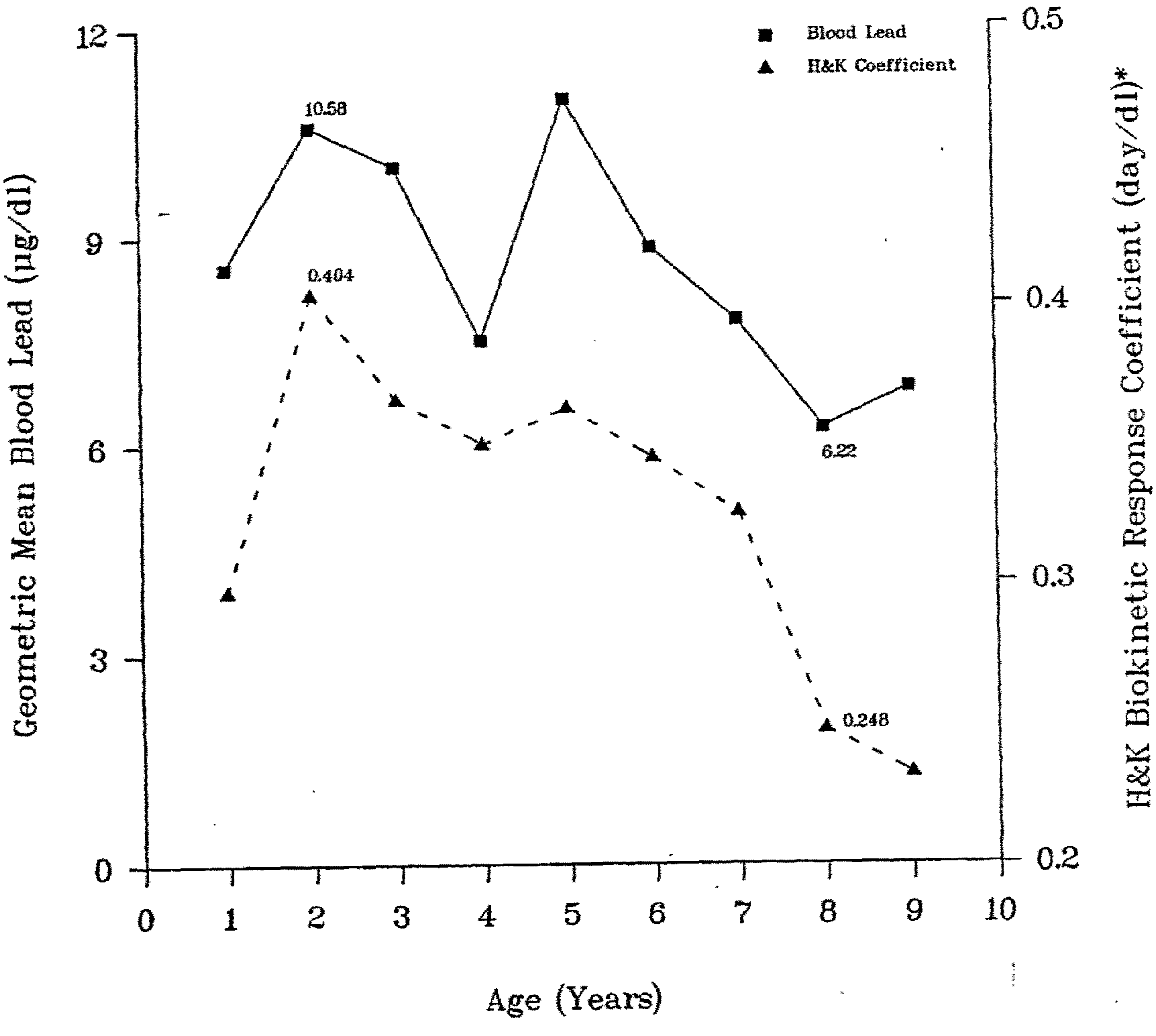


Figure C7

Bunker Hill Populated Areas, 1988 Geometric Mean Blood Lead and H&K Biokinetic Response Coefficient by Age



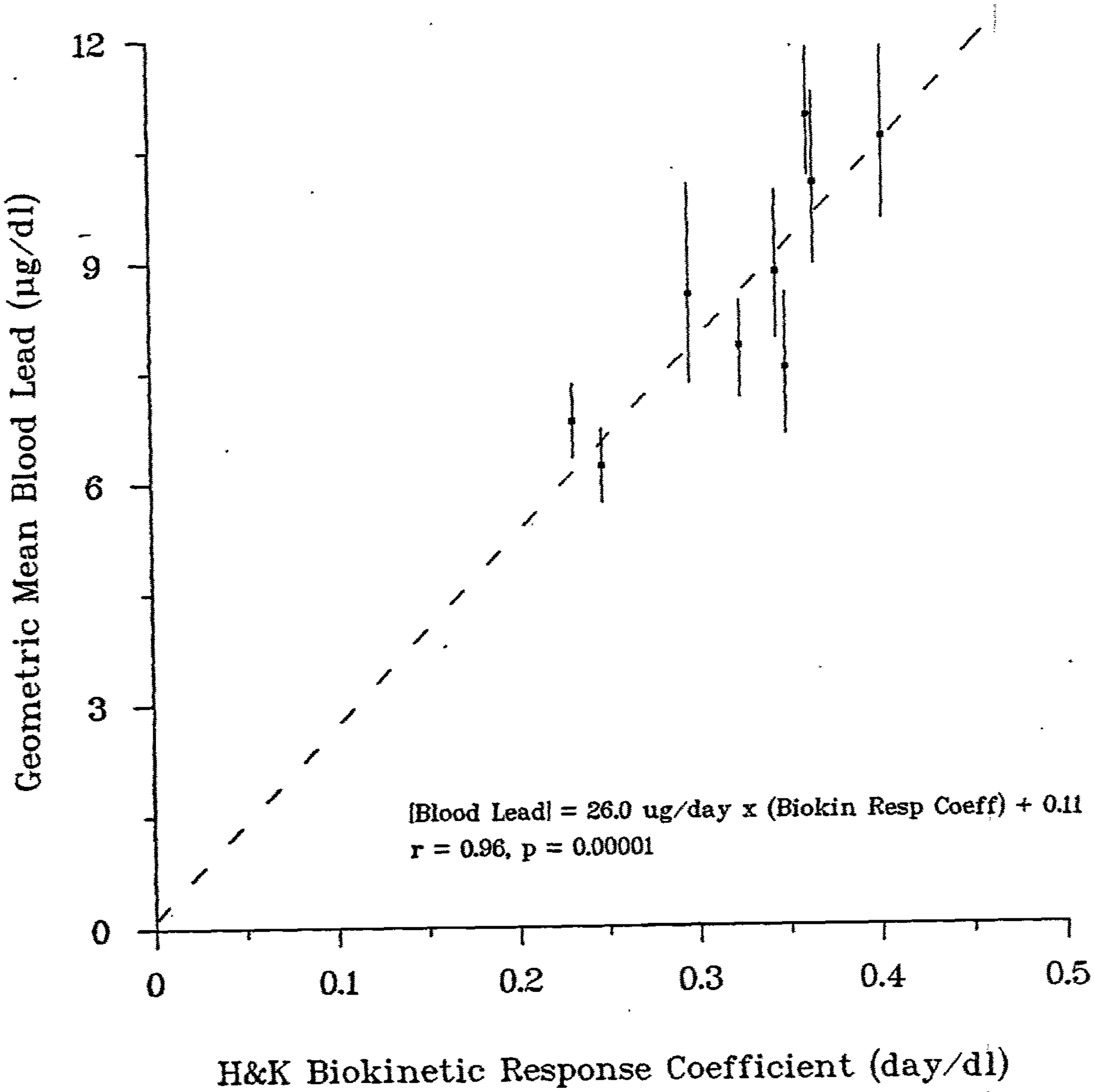
* Biokinetic response coefficient (µg/dl/µg/day = day/dl) from Harley and Kneip 1985

presents 1988 mean blood lead levels and biokinetic response coefficients by age. The mean daily absorbed lead at 2 years of age is 26.2 μg/day (10.58 μg/dl x $(0.404\ \text{day/dl})^{-1}$) and at 8 years of age is 25.1 μg/day (6.22 μg/dl x $(0.248\ \text{day/dl})^{-1}$). The similarity in lead uptakes at 2 and 8 years of age suggests that the primary factor controlling blood lead levels is lead metabolism and not behavior, since behavior is expected to be different between the ages of 2 and 8 years. A scatter plot of 1988 childhood (for ages ≤ 9 years) mean blood lead levels versus biokinetic response coefficients is presented in Figure C8 along with a linear regression line. The slope for the linear regression represents the mean daily lead uptakes (μg/day) for children. Daily lead uptake (mean daily absorbed dose) appears to be fairly constant for children ≤ 9 years of age. Data not on the line may be due to natural variability in monitoring and differences in mean childhood behaviors (such as ingestion rates and GI absorptions). A review of the data does not show a dependency of mean yard soil or house dust lead concentrations with age.

Mean lead uptakes in terms of daily absorbed lead (μg/day) are estimated, similar to the example for 1988 above, for the total site childhood population and for each of the communities (Smelterville, Kellogg/Wardner/Page, and Pinehurst) by year where blood lead survey data is available. Childhood lead uptakes (absorbed lead in μg/day) are estimated by linear regression analyses of mean blood lead levels against reciprocal lead clearance rates (blood lead response coefficients). Linear regressions for determination of mean lead uptakes are presented in Table C1. Calculated slopes which are representative of daily absorbed lead are low relative to real uptakes when mean blood lead levels are greater than 30-40 μg/dl; thus the calculated mean daily uptakes greater than approximately 100 μg/day, for example for total community, Smelterville and Kellogg/Wardner/Page in 1974 and 1975, are expected to be low estimates relative to actual values (U.S. EPA, 1989e). Childhood mean daily absorbed lead for each community is graphically presented in Figure C9. Mean lead uptakes since 1974 are greatest in Smelterville and least in Pinehurst. Childhood blood lead levels, in general, decrease with increasing distance from the smelter facility for the period 1974 through 1989. Since 1974, mean lead uptakes in Smelterville have been approximately 30% greater than for children in Kellogg/Wardner/Page. Children (ages ≤ 9 years) in Smelterville

Figure C8

Bunker Hill Populated Areas, 1988 Geometric Mean Blood Lead for Ages ≤ 9 Years vs H&K Biokinetic Response Coefficient



Vertical lines represent limits of standard errors about means for each age group.

TABLE C1

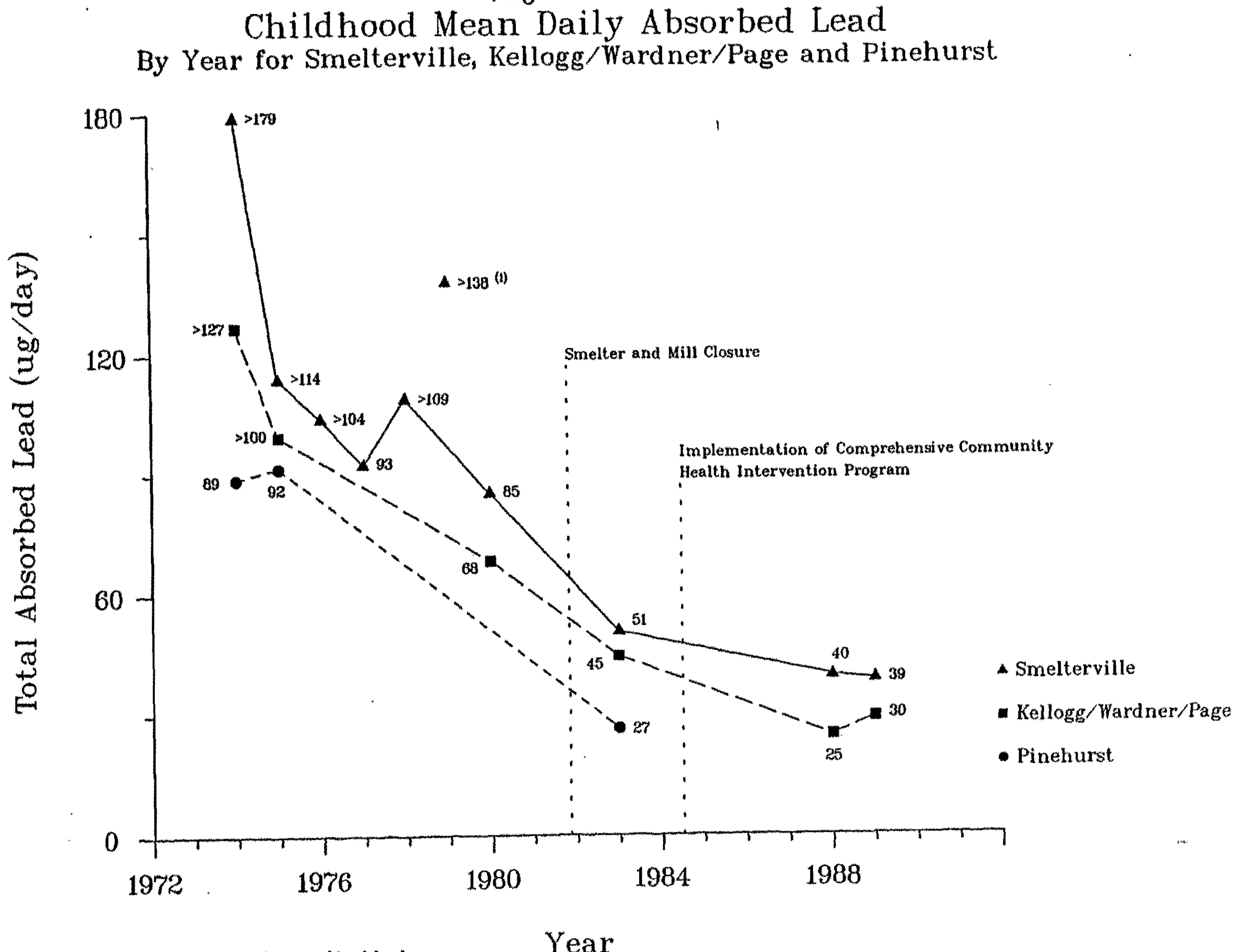
Linear Regressions for Determination of Mean Lead Uptakes

Blood Lead, ug/dl = Daily Absorbed Lead, ug/day x (Clearance Rate)$^{-1}$, day/dl + error

Year	Mean Daily Lead Uptake, ug/day (error/r/p)			
	Total Community	Smelterville	Kellogg/Wardner/Page	Pinehurst
1974	> 125 (5.6/.95/.00004)	> 179 (6.4/.96/.000009)	> 127 (5.2/.95/.00002)	89 (4.5/.94/.00004)
1975	> 100 (4.7/.95/.00002)	> 114 (8.0/.90/.0001)	> 100 (4.4/.95/.00002)	92 (1.5/.96/.00001)
1980	71 (4.4/.91/.0003)	85 (4.6/.93/.0002)	68 (4.2/.91/.0003)	
1983	38 (1.6/.93/.0001)	51 (2.8/.82/.003)	45 (0.9/.95/.00005)	27 (2.0/.83/.003)
1988	26 (0.11/.96/.00001)	40 (0.9/.55/.10)	25 (0.0/.95/.0005)	
1989	30 (0.33/.93/.0001)	39 (0.2/0.87/.001)	30 (0.08/.91/.0003)	

r = correlation coefficient
p = probability of error associated with r

Figure C9



(1) 1979 sample size small and mean blood lead levels high relative to other years.

exhibited approximately 70% greater lead uptakes, and in Kellogg/Wardner/Page about 40% greater lead uptakes, than for the population in Pinehurst during the same period.

Greatest lead uptakes occurred during a period in the mid-1970s when industrial activity and emissions associated with smelter operations were high. Mean lead uptakes and consequent blood lead levels in Smelterville for the period 1974 to 1980 were found to be highly dependent on and strongly correlated with mean air lead levels. Uptakes in 1983 following smelter and mill closure decreased to approximately 54% of levels in 1980 just prior to closure. Following the institution of a comprehensive community health intervention program in 1984, uptakes were further reduced by 26% and appear to have become somewhat constant. An apparent increase in lead uptake is exhibited in Kellogg/Wardner/Page between 1988 and 1989.

Total lead uptake is due to uptake contributions from each of four primary environmental media: air, diet, soil and dust. Table C2 shows total lead uptake as a summation of the uptakes associated with each of the critical environmental media. Site-specific input parameters for the uptake portion of the integrated uptake/biokinetic dose-response model are determined by application of the formulas presented in Table C2. Lead uptakes due to air and diet can be accurately predicted. However, there is less certainty associated with standard estimates of soil and dust lead uptakes, and the determination of such requires careful application of site-specific epidemiologic data. Lead levels in National market basket food have been declining over the years due to decreased emissions from automobile and point sources, lower lead levels in water, and less use of lead soldered food containers. Daily dietary lead intakes (μg/day) from National market basket food consumption for 1980-1989 from U.S. FDA total diet studies (U.S. EPA,1990e), not including water intakes, are as follows:

age (yr)	1980	81/82	82/84	84/86	86/88	88/89
6-month-old	34	20	17	10.1	4.1	4.8
2-year-old	43	30	23	13.3	5.3	5.0

Table C2
Equations for Lead Uptake

$$\overline{PbUT}_{(total)} = \overline{PbUT}_{(air)} + \overline{PbUT}_{(diet)} + \overline{PbUT}_{(soil)} + \overline{PbUT}_{(dust)}$$

where: $\overline{PbUT}_{m}$ = mean lead uptake from media m.

$$\overline{PbUT}_{(air)} = \sum \frac{n_i \times [Pb\text{-}air] \times VR_i \times 0.42}{N}$$

$$\overline{PbUT}_{(diet)} = \sum \frac{n_i \times DAC_i \times BW_i \times (MBI_i + 0.31 \text{ ug/kg/day})}{N}$$

$$\overline{PbUT}_{(soil)} + \overline{PbUT}_{(dust)} =$$

$$IR_{(S/D)} \times AC_{(S/D)} \times \sum \frac{n_i \times ([Pb\text{-}soil]_i \times (1 - MPF_i) + [Pb\text{-}dust]_i \times MPF_i)}{N}$$

$$= (IR_{(S/D)} \times AC_{(S/D)}) \times \text{Weighted } [Pb\text{-}soil/dust]$$

where:

n_i	=	number of children at age i
[Pb-air]	=	air lead concentration, ug/m^3, Table 4.13
VR_i	=	age-specific ventilation rate, m^3/day, Table 7.3
0.42	=	inhaled lead particulate absorption/deposition
N	=	total number of children = $\sum n_i$
DAC_i	=	age-specific dietary lead absorption coefficient, Table 8.8
BW_i	=	age-specific body weight, kg, Table 7.3
MBI_i	=	age-specific Market Basket lead Intake, ug/kg/day, Tables 7.12-7.14
0.31 ug/kg/day	=	chronic daily intake for lead in current site drinking water, Table 7.11
$IR_{(S/D)}$	=	mean soil/dust ingestion rate, gm/day (mg/day x 10^{-3} gm/mg)
$AC_{(S/D)}$	=	mean soil/dust lead GI absorption coefficient
$[Pb\text{-}soil]_i$	=	mean residential yard soil lead concentration, ug/gm, for age group i
$[Pb\text{-}dust]_i$	=	mean house dust lead concentration, ug/gm, for age group i
MPF_i	=	age-specific medium partition factor for house dust, Table 7.4

$IR_{(S/D)} \times AC_{(S/D)} \times 10^3$ mg/gm = Soil/Dust Lead Dose Coefficient, mg/day

All referenced Tables are from Protocol document.

Figure C4

1983 Blood Lead Summary Statistics by Age for Children ≤ 9 Years

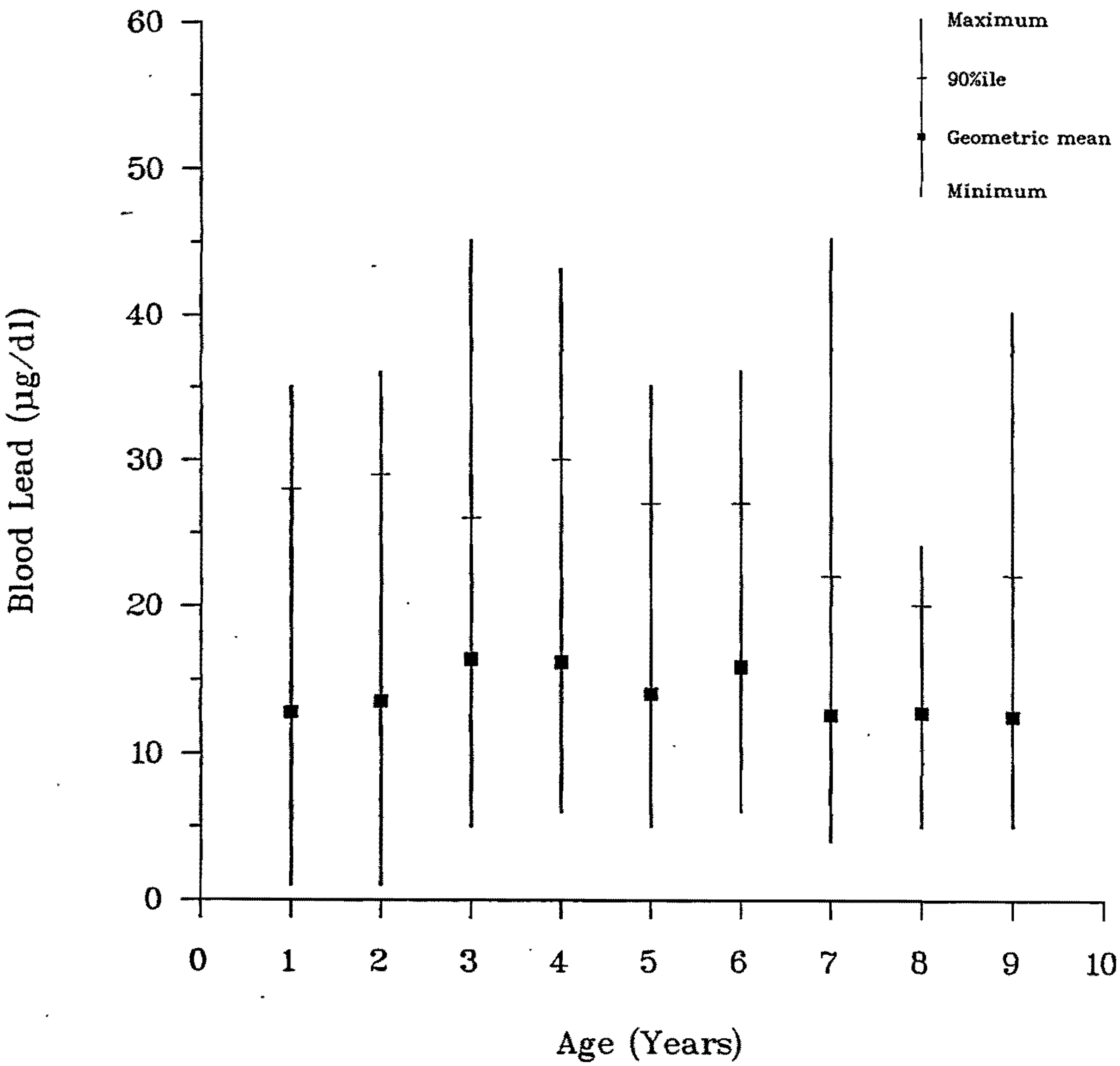
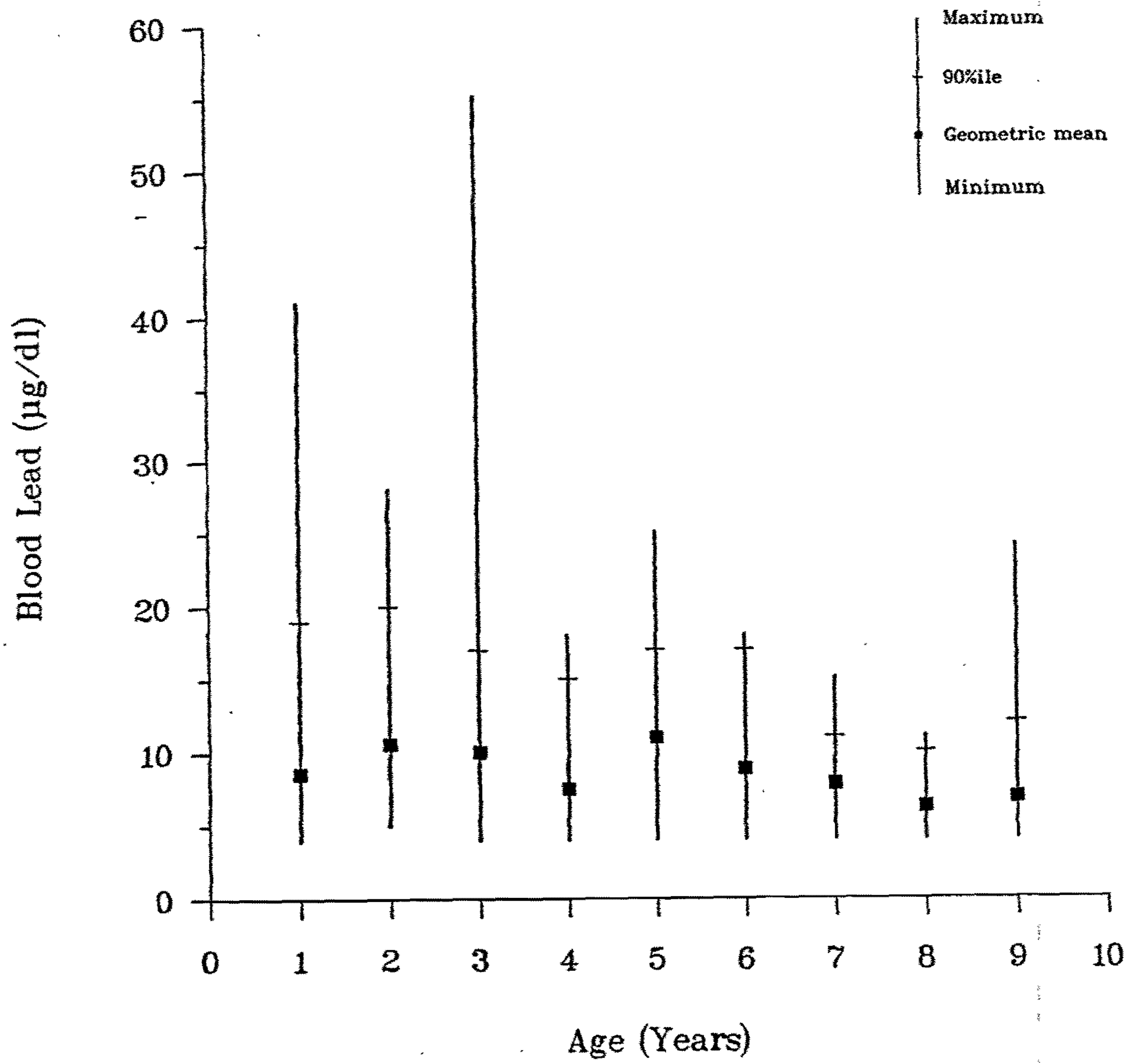


Figure C5

1988 Blood Lead Summary Statistics by Age for Children ≤ 9 Years



Lead uptake due to soil and dust ingestion is a product of the mean soil/dust lead concentration, ingestion rate and the lead GI (gastrointestinal) absorption coefficient. Soil and dust lead concentrations are measured, whereas the ingestion rate and GI Pb absorption coefficient require calculation. Both the ingestion rate and GI absorption coefficient are dependent on several site-specific factors, such as site climate and meteorological conditions, dust loadings, form and chemical species of lead contaminated solids, the presence of other associated metals competing with lead absorption, general population socioeconomic and nutritional status, and lead bioavailability. Therefore, consideration of site-specific influences on these factors are required to yield accurate model predictions. For this reason, the mean blood lead response is over-predicted for the Bunker Hill residential population if the default parameters recommended in the ECAO model for soil/dust ingestion rate and lead GI absorption coefficient for soil/dust are applied (see Section 8.2.2.2.3 of the PD).

The soil/dust ingestion rate and lead GI absorption coefficient cannot be determined independently of each other using site data; however, the product of the two terms can be calculated and is expressed as the **soil/dust lead dose coefficient.** The ingestion rate can be estimated if the absorption coefficient is known or is assumed to be a constant, or vice versa. The soil/dust lead dose coefficient is determined as follows:

$$\text{Soil/Dust Lead Dose Coefficient (mg/day)} = IR_{(S/D)} \times AC_{(S/D)}$$

where:

$$IR_{(S/D)} \times AC_{(S/D)} = \frac{PbUT_{(total)} - PbUT_{(air)} - PbUT_{(diet)}}{\text{Weighted [Pb-soil/dust]}} \times 10^3 \text{ mg/gm}$$

Values for $PbUT_{(total)}$ are from Table C1, by year. The terms are defined in Table C2 and values for each of the remaining terms are presented by year and community in Table C3. Dietary lead intake estimates for National market basket food consumption for 1988 and 1989 are presented above; public water supply lead concentrations are less than detection levels and assumed to be approximately 5 μg/L.

TABLE C3

Lead Uptakes for Determination of Soil/Dust Lead Dose Coefficient
(Mean for children ≤ 9 years of age)

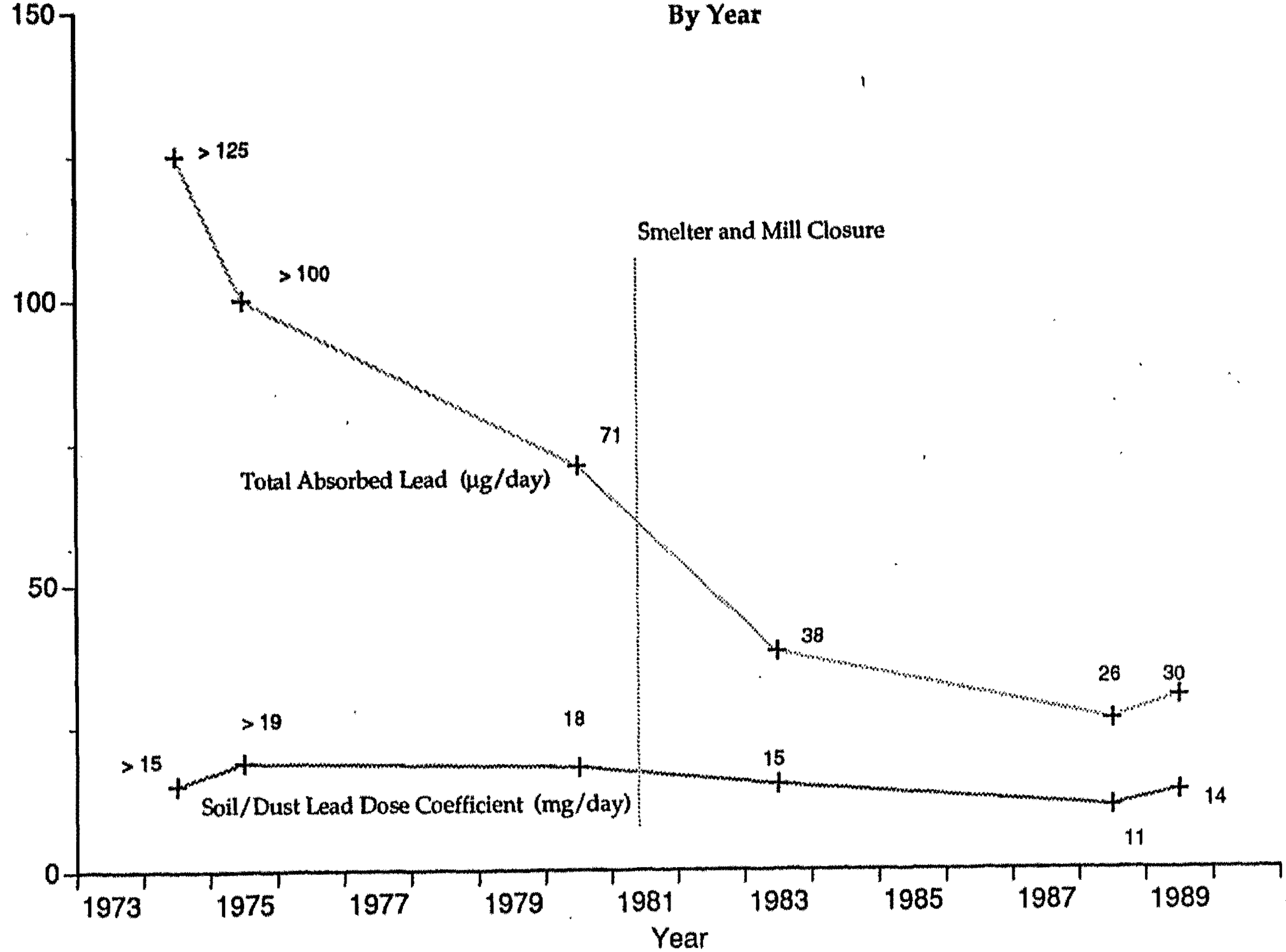
	Total Daily Uptake, µg/day	Dietary Uptake, µg/day	Air Uptake, µg/day	Weighted Soil/Dust Concentration, µg/day	Soil/Dust Lead Dose Coefficient, mg/day
1974					
Total population	> 125	23.0	25.8	5108	> 14.9
Smelterville	> 179	22.8	31.6	9473	> 13.2
Kellogg/Wardner/Page	> 127	23.1	31.0	5389	> 13.5
1975					
Total population	> 100	23.1	16.0	3242	> 18.8
Smelterville	> 114	23.7	19.6	3812	> 18.6
Kellogg/Wardner/Page	> 100	23.4	16.7	3939	> 15.1
1980					
Total population	71	15.5	14.1	2338	17.9
Smelterville	85	15.1	14.9	3370	16.4
Kellogg/Wardner/Page	68	15.6	13.7	2962	13.2
1983					
Total population	38	10.0	0.4	1823	14.9
Smelterville	51	10.4	0.5	3524	11.3
Kellogg/Wardner/Page	45	10.0	0.4	2469	13.9
1988					
Total population	26	3.6	0.3	1923	11.0
Smelterville	40	3.6	0.9	2009	17.6
Kellogg/Wardner/Page	25	3.6	0.3	2052	10.3
1989					
Total population	30	3.5	0.3	1921	13.6
Smelterville	39	3.5	0.8	2061	16.8
Kellogg/Wardner/Page	29	3.5	0.2	2090	12.1

Figure C10 graphically presents mean daily absorbed lead (in μg/day) and soil/dust lead dose coefficient (in mg/day) for children ages ≤ 9 years of age for the entire community surveyed since 1974. Reductions in mean lead uptake prior to 1984 can be attributed primarily to decreases in media lead concentrations. Between 1975 and 1983, lead uptakes were reduced by 60-70%, when only a 20% reduction in the soil/dust lead dose coefficient was observed. Mean lead uptake and blood lead level reductions between 1983 and 1988 were approximately 32% when the decrease in soil/dust lead dose coefficient for the same period was approximately 27%. Since 1983, reductions in mean lead uptake follow very closely the reduction in the soil/dust lead dose coefficient. Reductions in mean blood lead levels for area children since the 1970s are associated with decreased lead GI absorption and/or soil/dust ingestion rates, which may be a result of media intake reductions due to decreased contaminated dust loadings, decreased bioavailability of lead, interim remediation in the residential areas, and/or improved hygiene and public awareness of lead exposures in the community. Some of these factors are dependent on the differences in media and site characteristics associated with operating versus nonoperating smelter facilities.

A comparison of the soil/dust lead dose coefficients for Smelterville versus those for Kellogg/Wardner/Page since 1974 are presented in Figure C11. Smelterville children exhibit an average 20% greater lead dose coefficient since 1974 than children in Kellogg/Wardner/Page. This difference could be attributed to greater dust loadings, lead bioavailability and/or exposures to other (more contaminated and noncharacterized) soils and dusts in Smelterville. Also, the decrease in the soil/dust lead dose coefficient in Smelterville since 1975 was considerably less than that observed for Kellogg/Wardner/Page: ~ 0% for Smelterville versus ~ 21% for Kellogg/Wardner/Page. The community-wide reduction for the soil/dust lead dose coefficient displayed in Figure C10 is due to the reduction in Kellogg/Wardner/Page and not affected by Smelterville children. The mean soil/dust lead dose coefficient for Smelterville children was 1.7 times that for Kellogg/Wardner/Page children in 1988 and approximately 1.4 times greater in 1989.

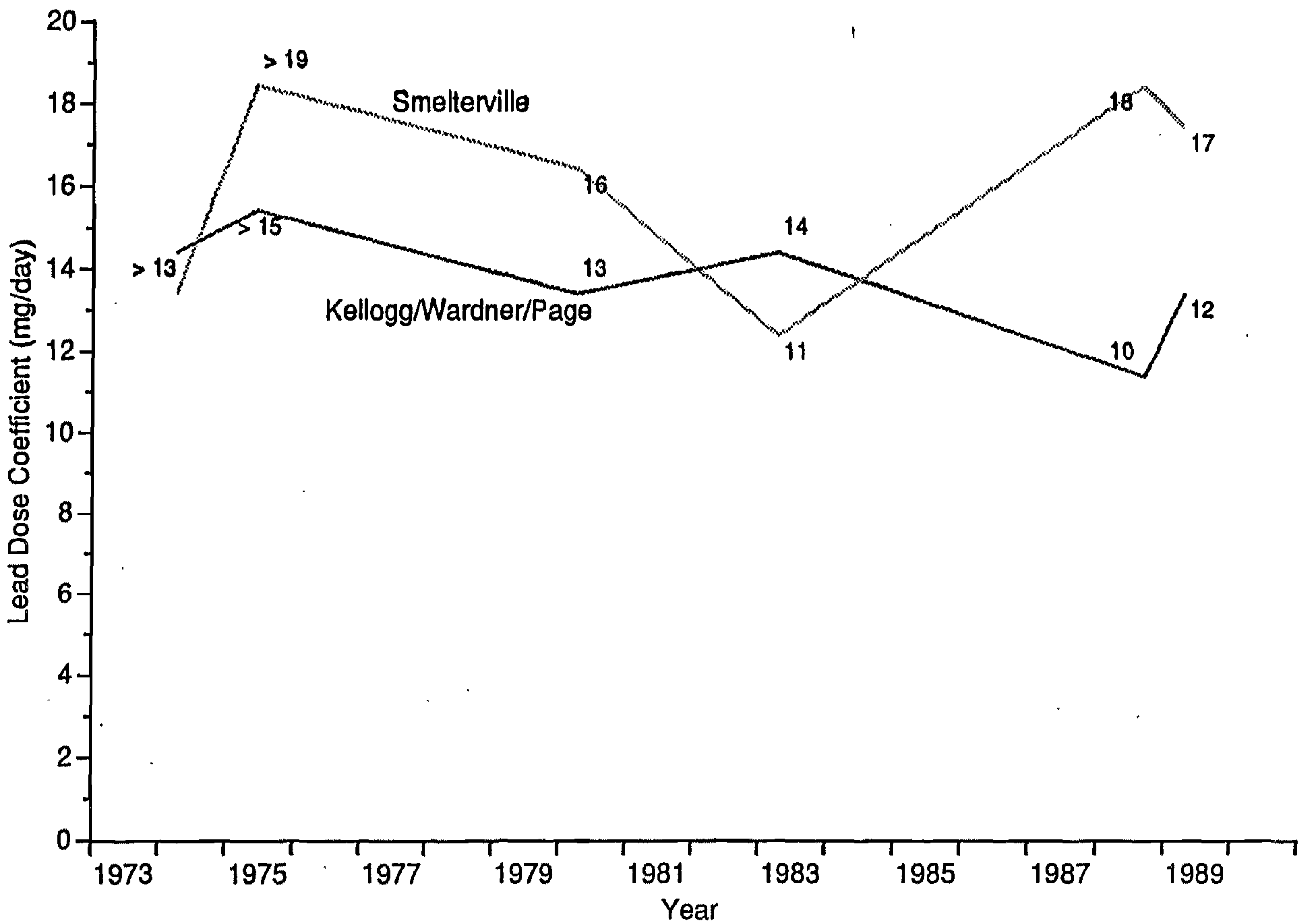
The community-wide mean soil/dust lead dose coefficient for children ages ≤ 9 years in 1989

Figure C10
Childhood Daily Absorbed Lead
and Soil/Dust Lead Dose Coefficient
By Year



Soil/Dust Lead Dose Coefficient = (Soil/Dust Ingestion Rate) x (Pb GI Absorption Coefficient)

Figure C11
Soil/Dust Lead Dose Coefficient
by Year for Smelterville and Kellogg/Wardner/Page



Lead Dose Coefficient (mg/day) = (Soil/Dust Ingestion Rate) x (Pb Absorption Coefficient) yields a mean soil/dust ingestion rate of 68 mg/day, if a 20% GI absorption rate is assumed [13.6/0.2 = 68]; and a 13.6% GI absorption rate is derived assuming a soil/dust ingestion rate of 100 mg/day [13.6/100 = 0.136]. During facility operations, a 20% GI absorption rate for lead in soil and dust was associated with a mean soil/dust ingestion rate of 94 mg/day [18.8/0.2 = 94]; and an 18.8% lead GI absorption rate was associated with a soil/dust ingestion rate of 100 mg/day [18.8/100 = 0.188]. The mean GI absorption coefficient and soil/dust ingestion rate for children ≤ 9 years of age living near an operating smelter in East Helena, Montana are reported to be 0.28 and 82 mg/day, respectively (U.S. EPA,1989e). These are also the recommended absorption and ingestion rates in the OAQPS dose-response model, which yield an equivalent mean soil/dust lead dose coefficient of 23 mg/day [0.28 x 82 mg/day] for children ≤ 9 years of age; a product that is more similar to that observed at this site during smelter operations, but greater than that observed under current conditions. The difference could be attributed to differences in the factors presented above that control soil/dust ingestion and lead GI absorption rates.

Extreme soil/dust lead dose coefficients were determined to be greater than 73 mg/day and 56 mg/day in 1988 and 1989, respectively. These were estimated for children exhibiting the greatest community blood lead level for each of the two years, which was in Smelterville for both years. Their daily lead uptakes were calculated and followed by a determination of the uptakes associated with soil and dust;

$$73 \text{ mg/day}_{(1988)} = ((55\ \mu\text{g/dl} \times (0.366 \text{ day/dl}_{(3\text{-year-old})})^{-1}) - 4.2\ \mu\text{g/day}_{(\text{diet + air})}) \times 10^3 \text{ mg/gm}/2009\ \mu\text{g/gm}, \text{ and}$$

$$56 \text{ mg/day}_{(1989)} = ((41\ \mu\text{g/dl} \times (0.345 \text{ day/dl}_{(6\text{-year-old})})^{-1}) - 4.3\ \mu\text{g/day}_{(\text{diet + air})}) \times 10^3 \text{ mg/gm}/2061\ \mu\text{g/gm} .$$

Assuming a 20% soil/dust Pb GI absorption, extreme soil/dust ingestion rates are determined to be approximately 365 mg/day [73 mg/day/0.20] and 280 mg/day [56 mg/day/0.20] for 1988 and 1989, respectively. Extreme soil/dust Pb dose coefficients for 1974 and 1975 are estimated to be approximately 53 mg/day for a 1-year-old and 77 mg/day for a 2-year-old, respectively; both children from Smelterville. Soil/dust Pb dose coefficients for children exhibiting the greatest blood lead levels (in Smelterville) during the period 1974-1989 are similar; whereas the typical response, in terms of the mean soil/dust Pb dose coefficient, decreased approximately 22% for the average child (in Kellogg/Wardner/Page) during the same period. These results suggest that exposure intervention to contaminated soil and dust for both the extreme and typical child in Smelterville between 1974 and 1989 has not been as effective as for the typical or mean child in other parts of the community.

Another way to account for extreme blood lead levels, other than increased or extreme ingestion rates of average concentration soil/dust, is by the intake of extreme concentration soil/dust at community mean ingestion and absorption rates. For 1988 and 1989, the TWA lead concentration for soil/dust would have to be 8,000 to 10,000 μg/gm at the community mean soil/dust lead dose coefficient in order to yield the observed extreme blood lead levels. These soil and dust lead concentrations are within the 93 to 99 percentile concentration range for soils and house dusts observed at the site. Regardless of the cause of extreme childhood blood lead levels observed in the community, whether due to greater than average soil and dust ingestion rates or extreme media concentrations, or both, reductions in lead uptake for the extreme child are expected to result from the lowering of both the mean and extreme soil and dust lead levels.

Validation of the Integrated Uptake/Biokinetic Dose-Response Model

Validation of the integrated uptake/biokinetic dose-response model for lead is accomplished by comparing the cumulative distribution function described by the predicted blood lead level and population variance with that of the observed distribution. This procedure is similar to that applied for validation of the model by the U.S. EPA with East Helena data (U.S. EPA, 1989e).

Model validation is accomplished for children ≤ 9 years of age for 1983 and 1989. Figure

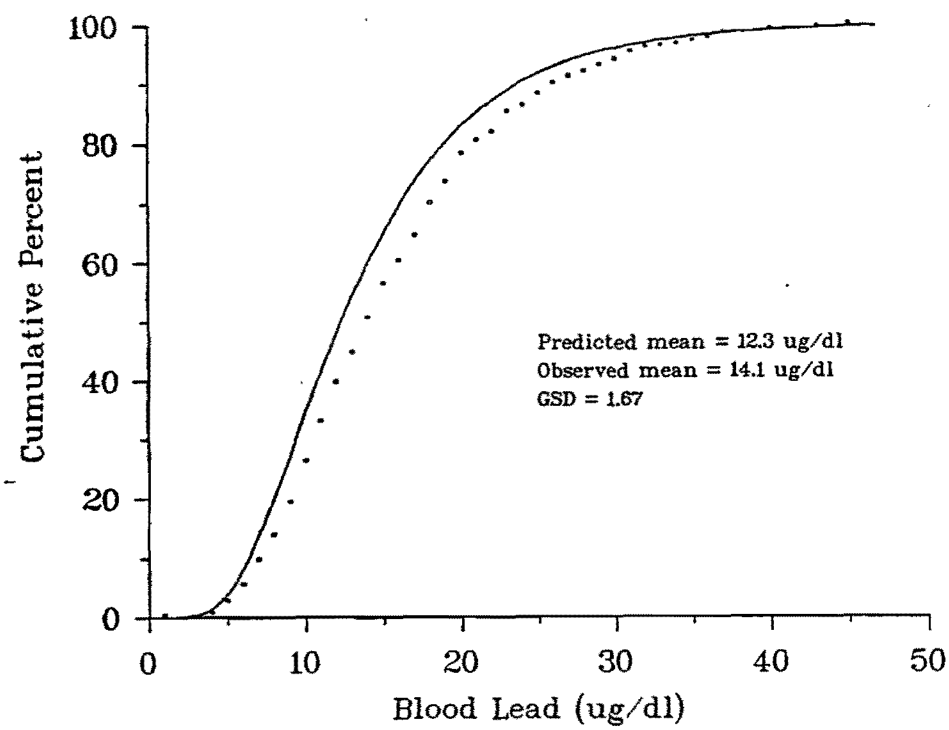
C12a shows that for 1983, application of a soil/dust lead dose coefficient of 14.9 mg/day yields a predicted distribution, indicated by the smooth line, similar to the observed distribution. The line in Figure C12a is described by a predicted mean blood lead of 12.3 μg/dl and a 1983 geometric standard deviation (GSD) of 1.67. Discrete data points represent the observed distribution which is the same as that plotted in Figure A6.4 in Appendix A (observed geometric mean = 14.1 μg/dl). A closer fit for mean blood lead is achieved when an 18.0 mg/day soil/dust lead dose coefficient is applied to yield a 43 μg/day mean lead uptake. A comparison of the predicted to the observed blood lead distributions for 1989 is presented in Figure C12b. The predicted distribution (smooth line) for children $\leq$ 9 years of age is defined by a mean blood lead of 9.8 μg/dl and a 1989 geometric standard deviation of 1.71. The observed distribution is shown by discrete data points with a geometric mean of 9.9 μg/dl (summary statistics for 1989 childhood blood lead levels are presented in Figure A6.6 in Appendix A). An inexact fit of the line to observed data at the distribution extremes shows some deviation of observed data from a log-normal distribution.

Model sensitivity to the effects of applying a range of medium partition factors (MPFs) for outdoor : indoor partitioning of soil and house dust exposures was examined and found to slightly affect the predicted mean blood lead value. Environmental and health survey data for 1988 were selected for this evaluation since it is representative of current conditions, no estimates or extrapolations are required for any of the environmental concentration input parameters, and the relative difference in the mean concentrations for soils and house dusts were greater than for other recent years. Thus, any effect on model results is expected to be greatest for the current population using 1988 data. Age-weighted partition factors (presented in detail in the PD and used in the generation of results presented in Figures C12a and b) were tested against the constant Blood Lead Partition Analysis ratio of 60/40 (soil/house dust). Application of the former (age-weighted) ratio yields a predicted mean blood lead that is approximately 6% less than the observed value for children $\leq$ 3 years of age, and 15% lower than the observed mean following application of a constant 60/40 ratio. This indicates that for children $\leq$ 3 years of age an age-weighted soil/dust partition factor (in this case 22/78) more accurately predicts the blood lead distribution than for a fixed 60/40

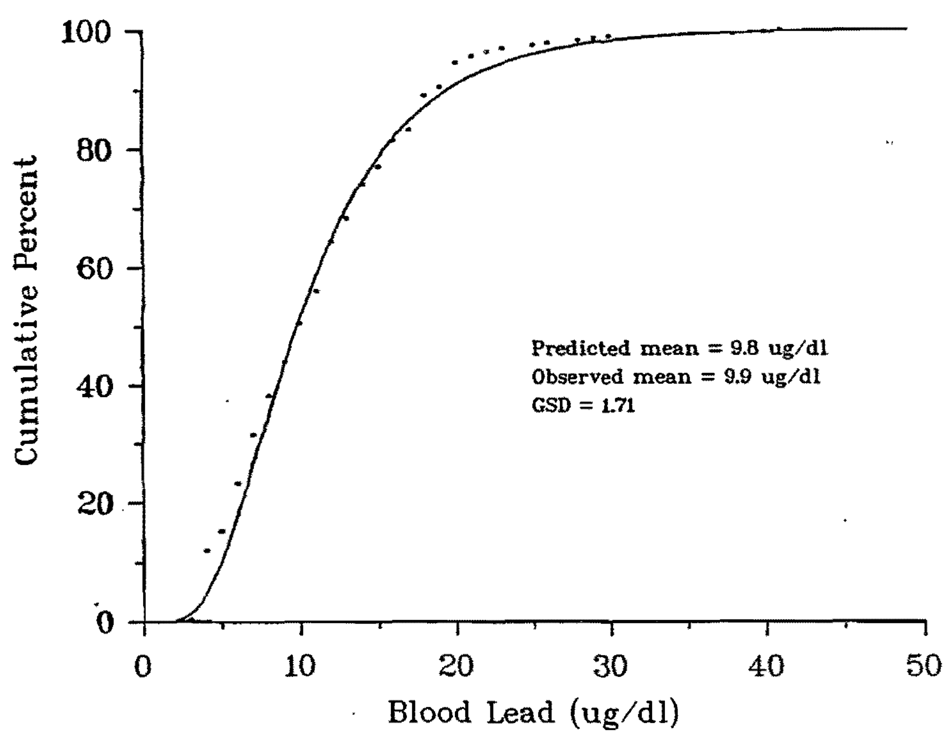
FIGURE C12

Comparison of 1983 Observed Childhood Blood Lead Distributions to Those Predicted by Integrated Uptake/Biokinetic Dose-Response Model*

a. 1983



b. 1989



* Line represents predicted distribution and discrete points represent observed data.

Note: Includes children ages ≤ 9 years.

ratio for direct soil and dust exposures. This analysis is also consistent with the observation that younger children spend a greater percentage of their time indoors than outside. The difference in model predictions, while discernable, is not considered large.

In conclusion, the integrated uptake/biokinetic dose-response model for lead can accurately predict mean blood lead response when appropriate environmental media lead concentrations and site-specific input parameters are selected. Blood lead variances for the site population are approximately log-normally distributed, and a population geometric standard deviation can be applied to the predicted mean blood lead value to estimate an observed distribution. Application of the dose-response model with site-specific input parameters has been demonstrated to predict blood lead levels for the site population over a range of environmental conditions. The integrated uptake/biokinetic dose-response model for lead with use of appropriate site-specific input parameters is suitable for determining remedial goals and for the evaluation and selection of remedial alternatives.

APPENDIX C, ATTACHMENT 1

Considerations for Prediction of Post-Remedial Blood Lead Response

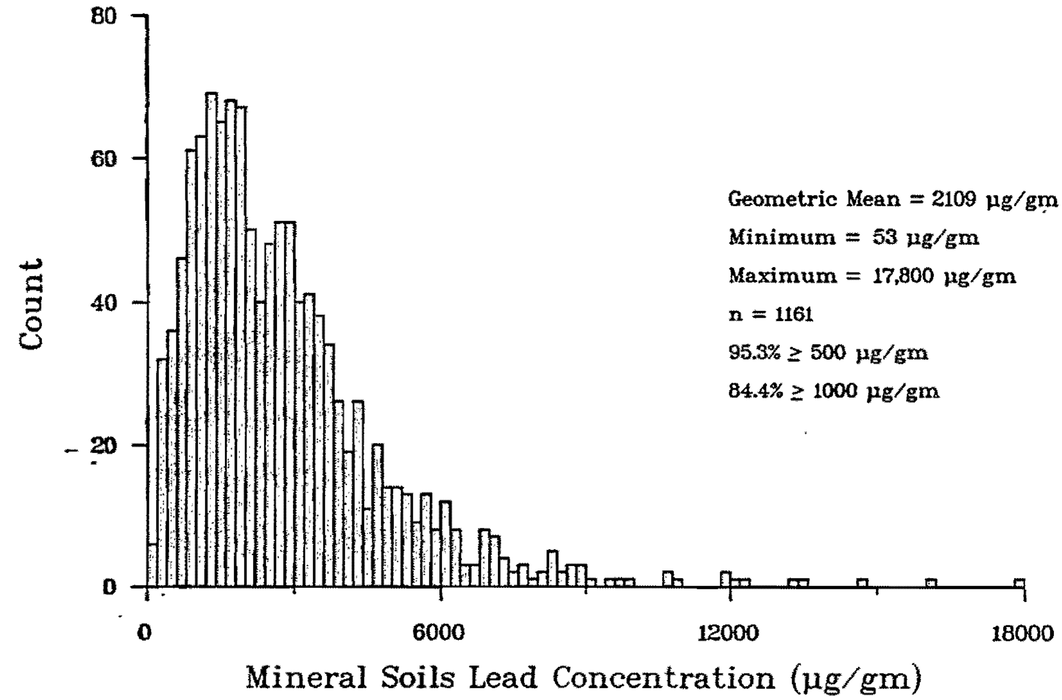
Site-specific GSDs for blood lead distributions describe the total variability associated with observed childhood blood lead levels. Two primary terms contribute to the observed GSDs; biological and physiological variabilities in lead absorption and blood lead response (biokinetics), and the variability in environmental media lead concentrations and childhood population exposures. Population blood lead variability in terms of a population blood lead GSD following remedial activities could be predicted to be different than recently observed site values. Depending upon the type and extent of remediation in the Populated and Non-populated Areas of the site, the distribution of and range in environmental lead concentrations and consequent population exposures could be narrowed and result in a lowering of the total variance predicted for community blood lead response. Consideration for application of a GSD less than a site observed value would be dependent upon the final selection and implementation of site remedies. Considerations for selection of a post-remediation blood lead GSD would include: a) the range and variability in final environmental contact media lead concentrations, b) potential for future increases in media lead concentrations due to any remaining lead contaminated sources, c) long-term effectiveness of remediation, and d) change and diversity in behavioral characteristics for future populations at the site. Population blood lead GSDs reported in other studies (Battelle 1990) include a value of 1.42 from the NHANES II, 1.25 to 1.30 for homogeneous populations with a single source of lead exposure, and 1.53 to 1.59 for heterogeneous populations with diverse sources. It has been suggested that a plausible "worst case" value for inter-individual variability in a homogeneous environment is a population blood lead GSD of 1.53. As a result, a range has been applied in the development of Table 7.1 to show the effects of variance (GSDs) on predicted blood lead response. Use of higher GSDs would require lower cleanup levels for protection of public health.

The selected clean-up level(s) for soil/dust is only one of several factors that determine the mean lead concentration levels in residential soil and house dust following remediation, which are presented in Table 7.1. Community mean soil and house dust lead concentrations are also dependent on the replacement soil lead concentration and the existing (prior to remediation) distribution of lead in residential soils and house dust. Figures C13 and C14 illustrate the relationships between these three factors (clean-up level, replacement soils concentration and existing distribution of lead concentrations) for residential soils and house dusts, respectively. Figure C13 shows the transformation of the existing mineral soil lead concentration distribution for the community (including Smelterville, Kellogg, Wardner and Page) when a 1000 μg/gm (ppm) cleanup threshold is applied and soils are replaced with soils of 100 μg/gm lead. A geometric mean soil lead concentration of 131 μg/gm would be attained with an associated range of 53 to 1000 μg/gm. Approximately 11% of the residential soil lead concentrations would exceed or be equivalent to 500 μg/gm. A similar transformation in the distribution of house dust lead levels is illustrated in Figure C14 as an example. The application of a 500 μg/gm dust lead cleanup threshold and concomitant residential soil lead replacement level of 100 μg/gm (yielding an effective house dust lead replacement/ maintenance concentration of 100 μg/gm) yields a community geometric mean house dust lead concentration of 109 μg/gm with a range of 69 to 500 μg/gm. A fourth factor which will control lead levels in residential soils and house dust following remediation is long-term recontamination by fugitive dust sources. These analyses assume permanence in the replacement soil/dust lead concentrations and do not consider the effects of recontamination of remediated properties.

Figure C13

Transformation of Distribution of Lead Concentration in Mineral Soils

a. 1986/87 distribution for Smelterville, Kellogg, Wardner and Page



b. Transformed distribution – substituting 100 ppm soils for soils > 1000 ppm

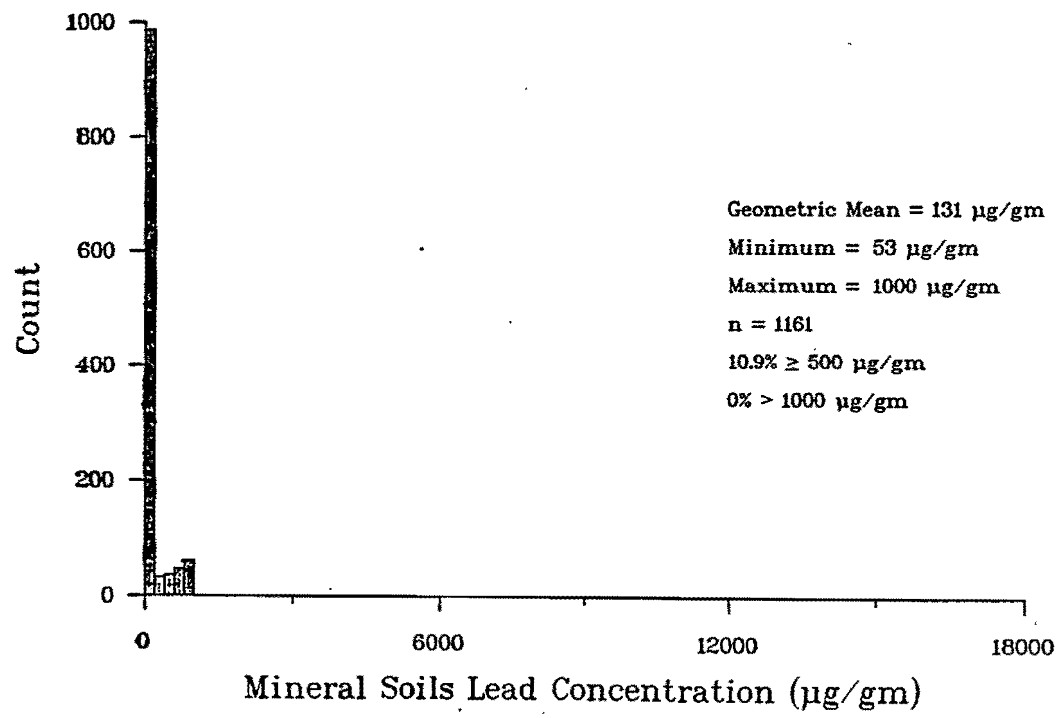
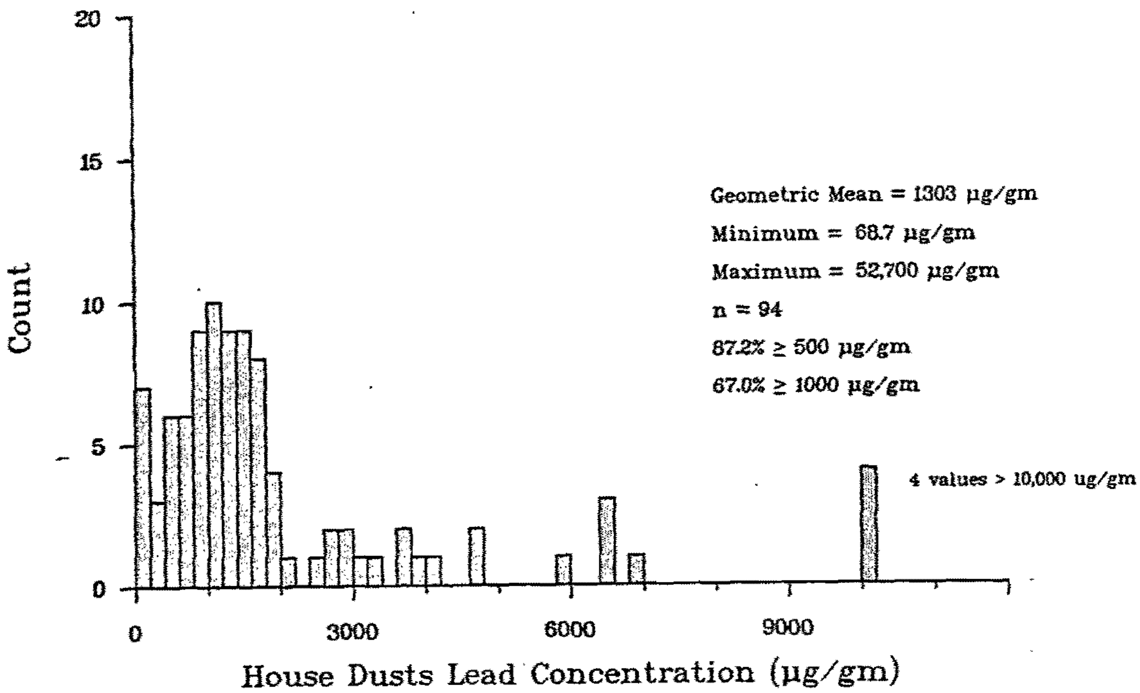


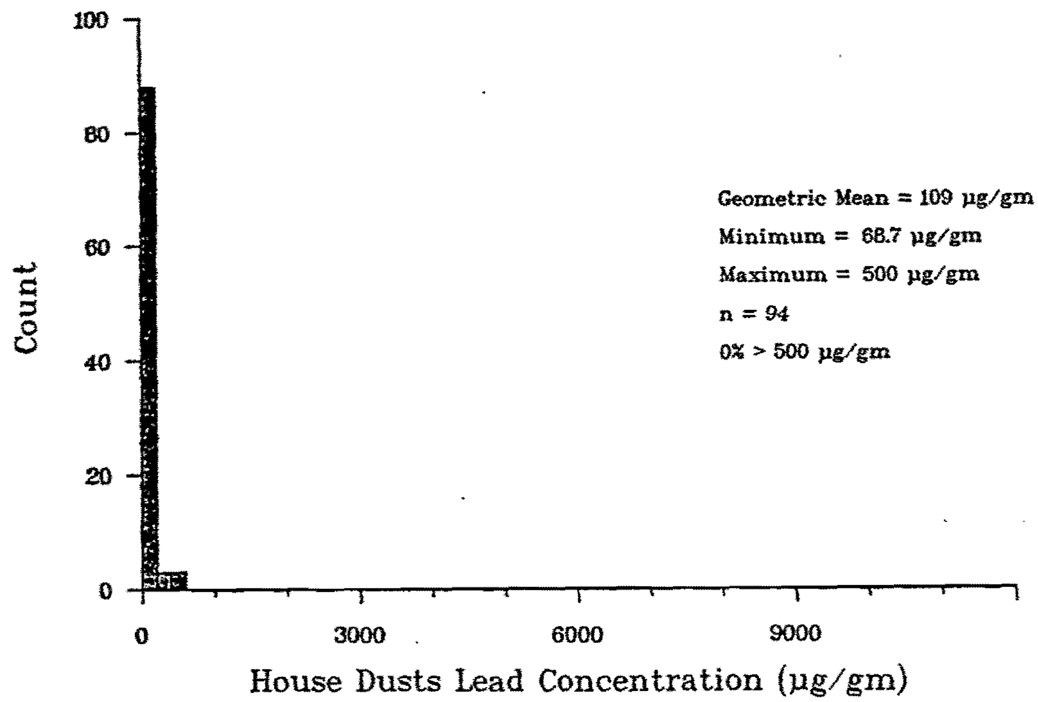
Figure C14

Transformation of Distribution of Lead Concentration in House Dusts

a. 1988 distribution for Smelterville, Kellogg, Wardner and Page



b. Transformed distribution – substituting 100 ppm dusts for dusts > 500 ppm



Appendix D

Status of the Integrated Uptake/Biokinetic Model for Lead as of August 1, 1990
by J. David Walker
OERR/HSED/TIB

Status of the IU/BK Model for Lead as of August 1, 1990

Summary based on summer 1990 work

by

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Status of IU/BK Model for Lead as of August 1, 1990

Setting soil-lead cleanup standards

No current EPA standard exists for soil cleanup levels for lead, though interim guidance (OSWER Directive #9355.4-02) sets the level at 500-1000 ppm for residential settings for the Superfund program. No reference dose or cancer potency factor exists for lead, nor are such values likely to be established due to uncertainties in detecting effects of low level exposure to lead. In the absence of guidelines typically used for risk assessment, a modeling approach has been investigated as a means of establishing soil cleanup levels for lead. Developed by Harley and Kneip (1985, New York Univ.) and used by EPA's Office of Air Quality Planning and Standards (OAQPS) to set the National Ambient Air Quality Standards (NAAQS) for lead, the Integrated Uptake/Biokinetic (IU/BK) Model has been distributed by the Environmental Criteria and Assessment Office (ECAO) as a potential method for determining cleanup levels for soils contaminated with lead.

The model predicts total lead uptake for children 0-7 years of age by combining lead concentrations measured in media associated with various exposure pathways (soil, dust, diet, water, air) with age-specific factors for intake (inhalation and ingestion) and uptake (absorption) through each of the pathways. Then the total lead uptake is translated into a mean blood lead (PbB) concentration using linear absorption/distribution kinetic assumptions based on animal and human studies (Kneip et al., 1983; Harley and Kneip, 1985); Figure 1 shows the absorption/distribution pathways upon which the model is based and their respective kinetic constants (U.S. EPA, 1990b). A log normal distribution curve is then produced that is defined by the chosen geometric standard deviation (GSD) about the mean PbB value; the model output also defines what percentage of children have PbB levels above or below a chosen cutoff PbB level.

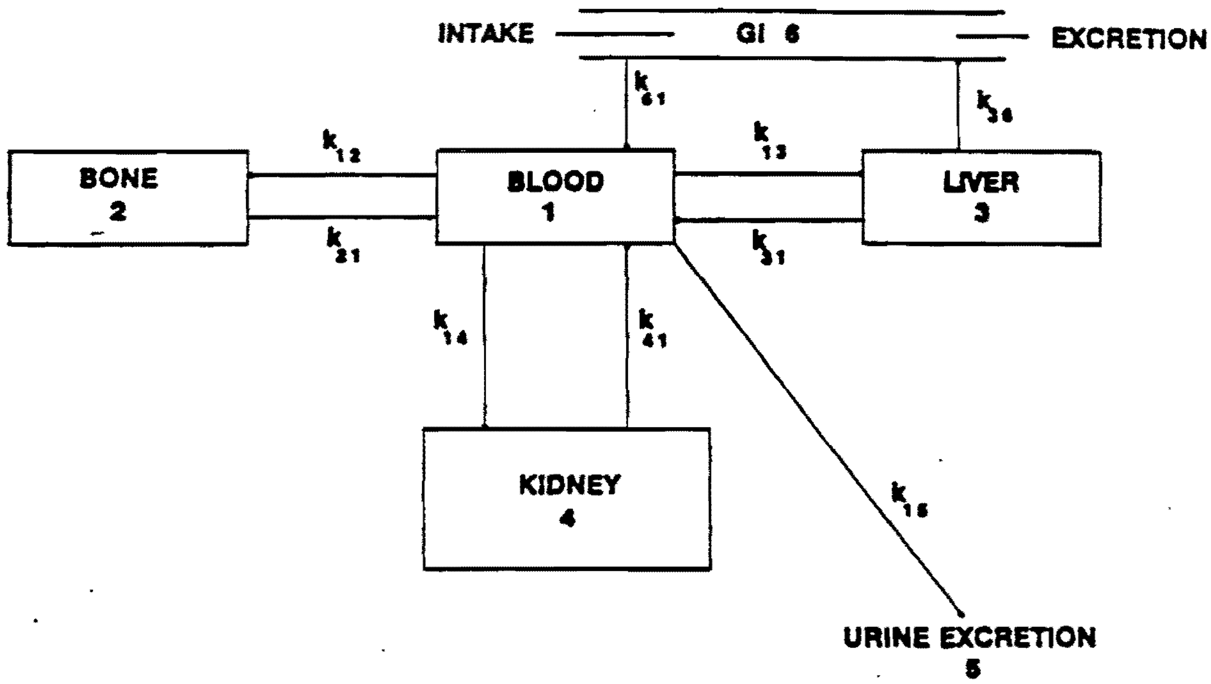
Blood lead levels are generally viewed as the most practical way of determining recent and subchronic exposure to lead (ATSDR, 1988). The PbB level of concern has steadily dropped as studies have become more sensitive; the present action level of 25 ug/dL set in 1985 is currently being reviewed by the Centers for Disease Control (CDC) and will certainly be lowered. Indications from the CDC are that 10 ug/dL will be considered a community action level and 15 ug/dL will be a level requiring a child be placed in a follow-up program (Falk, 1990).

Model Sensitivity

The model is flexible in that it allows for site-specific input data and/or nonsite-specific default values; as new studies are conducted, the default values can be updated to reflect clearer understanding of a given exposure factor. Table 1 shows the default values for 2-3 year old children used in the most

Figure 1

Schematic Model of Lead Metabolism in 2-Year-Old-Children, with Compartmental Transfer Rate Constants



$k_{12} = 0.13$	$k_{31} = 0.03$	$k_{15} = 0.08$
$k_{21} = 6.11 \times 10^{-4}$	$k_{14} = 0.02$	$k_{36} = 0.14$
$k_{13} = 0.07$	$k_{41} = 0.07$	$k_{61} = 0.30$

Table 1

Default values: Integrated Uptake/ Biokinetic Model for Lead

For 2 to 3 year old children exposed to lead in air, diet, dust, soil, and drinking water.

Parameter	Default value
1. Outdoor air lead (ug/m3)	0.2
2. Indoor air lead (ug/m3)	0.06
3. Time spent outdoors (hour/day)	3
4. Time weighted average for air (ug/m3)	0.10
5. Breathing volume (m3/day)	5
6. Lead intake from breathing (ug/day)	.5
7. % Respiratory deposition/ absorption	32
8. Lead uptake from air (ug/day)	0.2
9. Lead intake from diet (ug/day)	29
10. % Gastrointestinal absorption	50
11. Lead uptake from diet (ug/day)	14.5
12. Outdoor soil lead (ug/g or ppm)	200
13. Indoor dust lead (ug/g or ppm)	200
14. Daily soil-dust ingestion (g/day)	0.1
15. Weighting factors (soil/dust)	45/55
16. Lead intake from dust and soil (ug/day)	20
17. % Gastrointestinal absorption	30
18. Lead uptake from dust and soil (ug/day)	6.0
19. Drinking water lead (ug/L)	9
20. Drinking water intake (L/day)	.5
21. Lead intake from drinking water (ug/day)	4.5
22. % Gastrointestinal absorbance	50
23. Lead uptake from drinking water (ug/day)	2.3
24. Lead intake from leaded paint	0
25. Total lead uptake (ug/day)	23

Percentage contribution: 63% diet, 26% soil, 10% water, 1% air recent version of the model, Lead3. As indicated at the bottom of the table, food accounts for 63% of the total intake of lead when only default values are run in the model. This gives a PbB distribution as seen in Figure 2 in which 15% of the children aged 2-3 years would have PbB levels above 10 ug/dL. Most users of the model agree that the diet default values (1981/1982 levels) in Lead3 are high, and most use the 1990 FDA predicted values (Cohen, 1988a,b) for current model predictions. Table 2 provides a view of declining dietary lead intakes for children aged 1-6 years while Table 3 gives more recent dietary lead intakes for 6-month-old and 2-year-old children.

Table 2

Age-Specific Total Dietary Lead Intake (ug/day) for 1978-1983 (Sledge, 1986) and predicted for 1990 (Cohen, 1988a,b)

Age (years)	1978	1979	1980	1981	1982	1983	1990
1-2	45.8	41.2	31.4	28.8	26.0	19.3	8.9
2-3	52.9	48.0	36.9	33.8	30.6	24.1	10.4
3-4	52.7	47.8	36.9	33.7	30.6	23.0	10.7
4-5	52.7	47.8	36.9	33.8	30.7	22.0	10.8
5-6	55.6	50.3	38.7	35.5	32.2	23.2	11.3

Note: 1978-1983 values calculated using year-specific FDA data on food lead content and Multiple Source Food Modeling methodology described in Chapter 7 of U.S. EPA, 1986.

Table 3

Daily Dietary Lead Intake (ug/day) for 1980-1989 from FDA Total Diet Studies

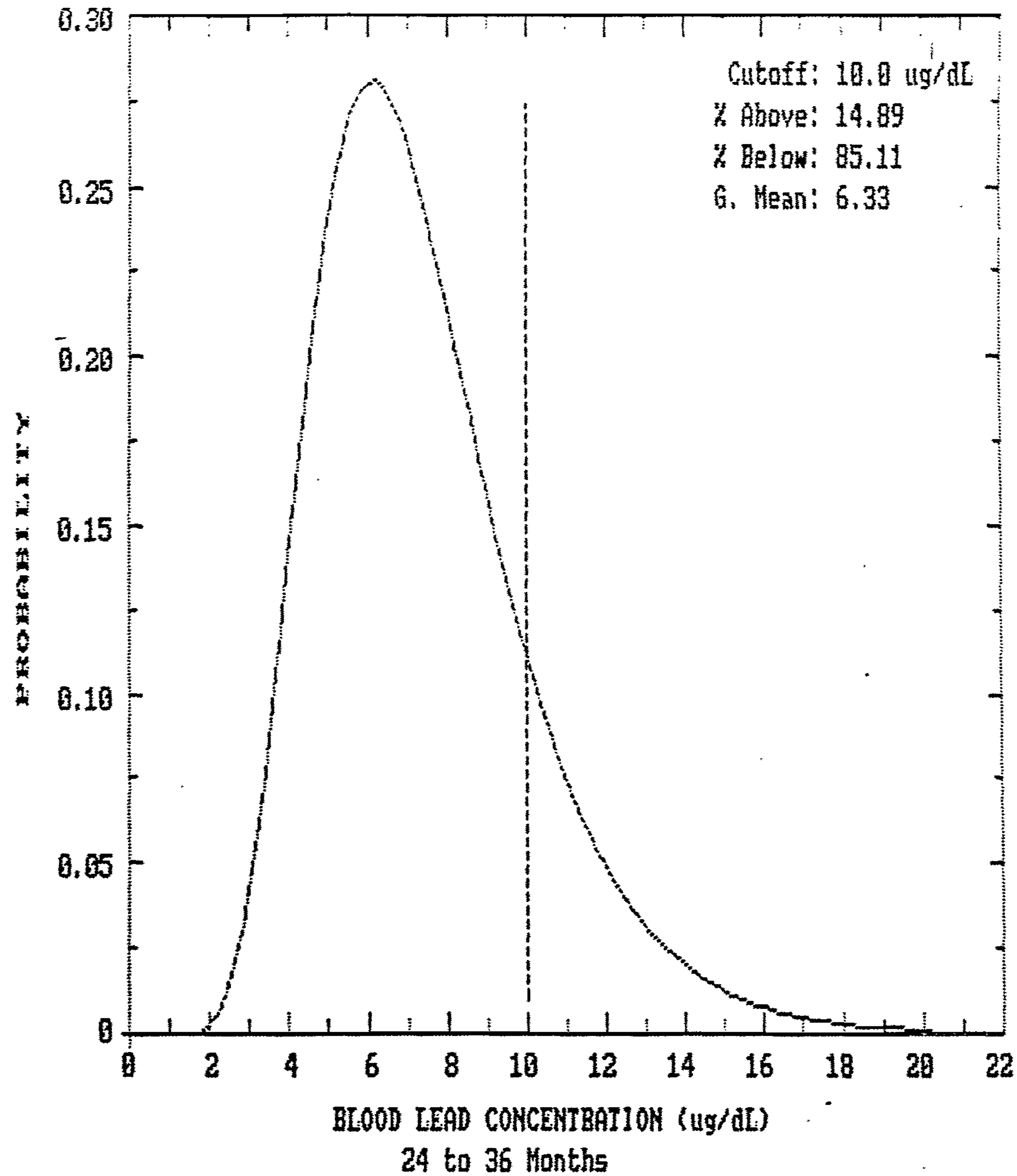
age	1980	81/82	82/84	84/86	86/88	88/89
6-month-old	34	20	17	10.1	4.1	4.8
2-year-old	43	30	23	13.3	5.3	5.0

Note: Unpublished 1984-1989 data received through personal communication (Gunderson, 1990) with the author of the 1980-1984 data (U.S. FDA, 1988).

The Food and Drug Administration (FDA) is responsible for regulating lead in the diet. Efforts began in the 1970s to lower the levels of lead in the diet. Lead levels in food have been declining due to decreased emissions from automobile and point sources, lower lead levels in water, and less use of lead soldered food containers (U.S. EPA, 1989a). For example, in 1979, over 90% of food cans contained lead solder, but by 1986 the level had dropped to an estimated 20%; a 77% reduction in

Figure 2

Blood lead distribution using all default parameters, GSD = 1.42.



canned food lead was accomplished in the period 1980-1985 according to data provided to FDA by the National Food Processors Association (ATSDR, 1988). The amount of imported canned foods containing lead solder is unknown, however.

The FDA's Total Diet Study (TDS), also known as the Market Basket Study, establishes reference values for lead contents of typical diets for children and adults. Specifically, the TDS involves retail purchase of foods in regional metropolitan areas, preparation of the foods, and individual analyses of 234 items depicting the diets of 8 population groups from infants to elderly adults. The TDS is based on two nationwide surveys: USDA's 1977-1978 Nationwide Food Consumption Survey and the 1976-1980 National Center for Health Statistics' Second National Health and Nutrition Examination Survey (NHANES II); the 234 foods, 33 of which include commercially prepared infant and junior foods, were chosen to best represent the more than 5000 foods identified in the surveys. Dietary intakes of over 100 analytes are determined and most analyses employ multiresidue analytical methods. Also, the analytical procedures used in the TDS are modified to permit quantitation at levels 5-10 times lower than those used in FDA regulatory enforcement as food preparation may reduce levels of chemical residues (U.S. FDA, 1988).

Reanalysis using the model and the 1990 diet values (Table 2) along with the other default values yields the plot seen in Figure 3 in which 99.5% of the children would have PbB levels below 10 ug/dL. With these input values into the model the soil/dust levels could average 350 ppm lead and still yield a distribution in which 95% of the children would have PbB levels below 10 ug/dL. Should all exposure parameters except for soil/dust be set to zero (i.e., no lead intake from air, water, or diet) then soil cleanup levels would have to be set at 600 ppm lead in order to have 95% of the children with PbB levels below 10 ug/dL; this analysis was done to determine the upper limit for soil cleanup levels based on the current model assumptions concerning soil/dust intake and uptake. These values are shown in Table 4 along with the soil cleanup levels which would be required should the PbB cutoff value be set at 15 ug/dL. For the conditions modeled in Table 4, a soil/dust level which places 95% of children below 10 ug/dL also has 99.9% of them below a 15 ug/dL level.

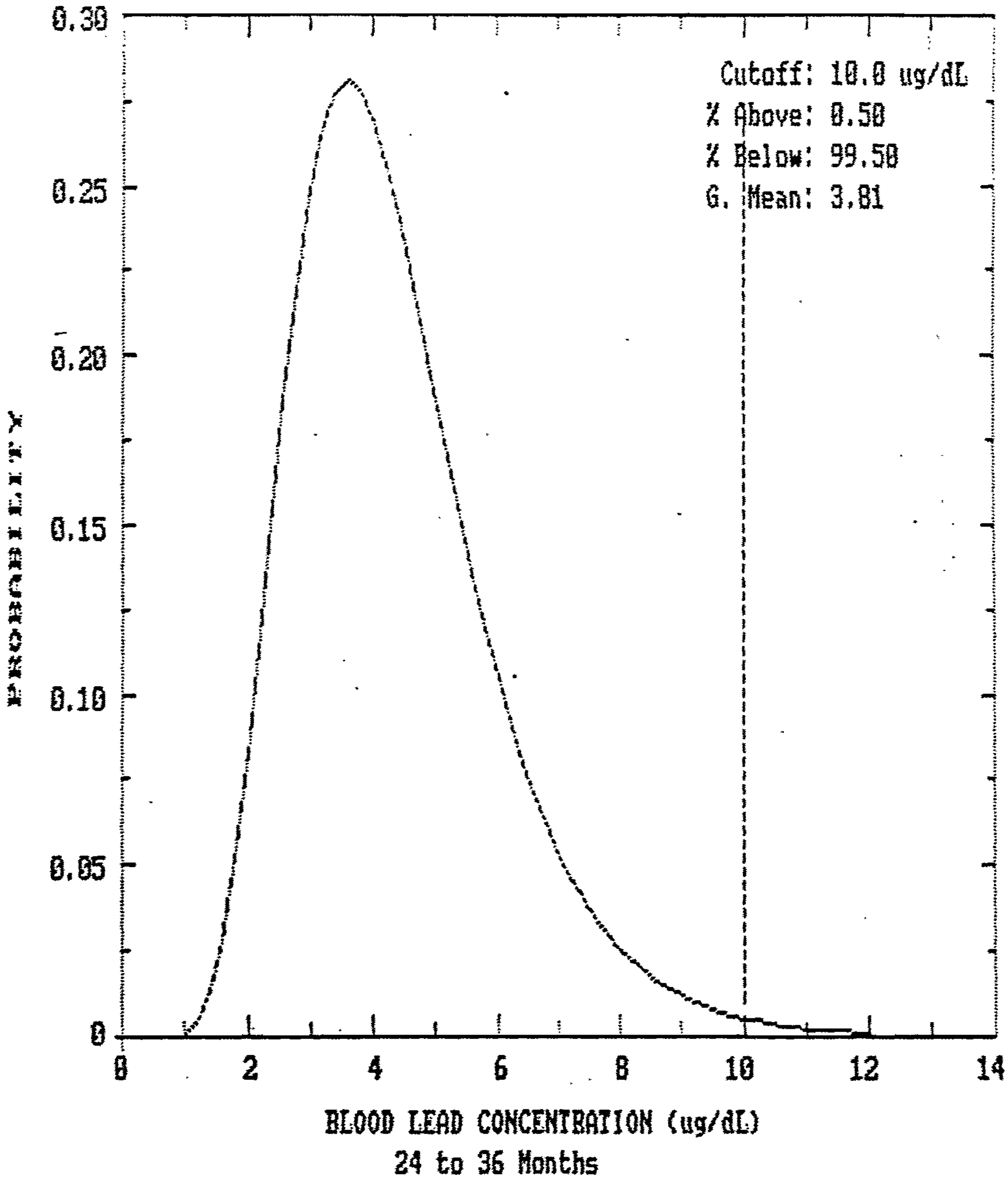
Table 4

Required soil/dust cleanup levels (ppm) to keep 95% of children aged 2-3 years below cutoff:

	10 ug/dL	15 ug/dL
Current model, all default	60	350
Default, 1990 FDA diet values	350	640
All other parameters set to zero	600	890

Figure 3

Blood lead disrtibution using 1990 predicted diet values, all else default, GSD = 1.42



Using the 1990 diet values and soil/dust levels set at 350 ppm lead, soil/dust accounts for 58% of the total lead uptake with diet, water, and air contributing 29%, 13%, and 1% respectively. The model is therefore very sensitive to changes in the soil/dust levels themselves or the soil/dust ingestion rate, the soil/dust absorption value (bioavailability), or the default dust value if only soil levels are measured at a site. Changes in the diet values also can greatly affect the projected cleanup level, as seen in Figures 2 and 3. Changes in the water or air values have limited effects on soil/dust cleanup levels due to their minor contribution to the total lead uptake.

Although data is limited on the absorption of lead from nonfood items, studies point to a soil/dust absorption value of 30%, the current model default (U.S. EPA, 1986). This value has been contested by the potentially responsible party (PRP) at the Sharon Steel/Midvale Tailings mining site who claims that mine tailings are less bioavailable due to larger particle size and different chemical species than the soils used in the studies cited above (ARCO, 1989). A study funded by EPA testing the bioavailability of mine tailings using swine has been conducted in Region 8 by Dr. J. LaVelle. Though the final report is not yet completed, preliminary accounts from the investigators indicate that the swine study will confirm the 30% absorption value. Table 5 shows how variations in the absorption value would affect soil/dust cleanup levels.

Table 5

Soil/dust cleanup levels (ppm) required with different soil/dust absorption values:

Absorption value %	cutoff 10 ug/dL soil/dust level	cutoff 15 ug/dL soil/dust level
50	200	385
40	250	480
30	350	640
26	400	740
21	500	920
17	600	1130
15	700	1280
13	800	1480
11	900	1750
10	1000	1920
5	2000	3850
4	2500	4800
3	3500	6400
2	5000	9600
1	10000	17500
0	infinity (no cleanup)	infinity

Note: 1990 diet values, all else default, 95% of children have PbB levels below the cutoff values

Soil ingestion rates for children are difficult to measure and results from the studies completed to date (Binder et al., 1986; Calabrese et al., 1989; Davis et al., 1990; Van Wijnen et al., 1990) have recently been called into question by Calabrese, the principal investigator of one of the studies (Calabrese, 1990). The current model default value is 100 mg/day; the value presently used to determine Reasonable Maximum Exposure (RME) at Superfund sites for soil ingestion is 200 mg/day. Validation exercises (discussed below) carried out on the model by some researchers (Hoffnagle, 1988; U.S. EPA, 1990a) have shown that the model over-predicts actual PbB means unless soil ingestion values ranging from 40-60 mg/day are used. According to the Calabrese study, where the appropriate tracer element (Zirconium) was used, a value as low as 20 mg/day may be appropriate for soil ingestion (Calabrese, 1990), though further studies are certainly needed given the doubts cast on all the soil ingestion studies. Table 6 shows how variations in the soil ingestion value would affect soil/dust cleanup levels.

Table 6

Soil/dust cleanup levels (ppm) required with different soil/dust ingestion rates (mg/day intake):

Ingestion rate	cutoff 10 ug/dL soil/dust level	cutoff 15 ug/dL soil/dust level
200	180	325
150	270	490
100	355	645
80	440	805
60	590	1070
40	885	1610
20	1770	3220

Note: 1990 diet values, all else default, 95% of children have PbB levels below the cutoff values

Table 7 gives soil/dust cleanup levels required under different dietary lead intakes for 2-3 year old children based on FDA values presented in Tables 2 and 3. Table 7 shows that the dietary intake of lead was so high for the years 1978-1981 that no level of soil cleanup would have kept 95% of children below a 10 ug/dL cutoff. With the current lower levels of lead intake from the diet, soil/dust becomes the major source of lead intake for the average child.

Table 7

Soil/dust cleanup levels (ppm) required with different dietary intakes of lead (ug/day) for 2-3 year old children:

dietary lead intake (corresponding year)		cutoff 10 ug/dL soil/dust level	cutoff 15 ug/dL soil/dust level
(1978)	53	NA	NA
(1979)	48	NA	60
(1980)	37	NA	230
(1981)	34	NA	280
(1982)	31	35	320
(1983)	24	140	430
(1984-86)	13	310	600
(1986-88)	5.3	430	720
(1988-89)	5.0	440	730

Note: All other parameters set to default, 95% of children have PbB levels below the cutoff values above. NA means that the diet values are so high that no level of soil cleanup would give the required level of protection.

Changing the geometric standard deviation (GSD) can also have major effects on the soil/dust cleanup level, not by altering the mean as was accomplished by the changes described above, but by altering the shape of the distribution curve. A low GSD signifies a high confidence in the geometric mean and the distribution curve is high and narrow. A high GSD by contrast signifies lower confidence in the geometric mean and the distribution curve is shorter and more broad with a long tail in the high PbB regions. Figure 4 shows curves A,B, and C with GSD's of 1.50, 1.42, and 1.35 respectively which would require soil cleanups of 280 ppm, 350 ppm, and 425 ppm lead respectively in order to have 95% of children with PbB levels below 10 ug/dL. Actual GSD values from several PbB studies are presented in Table 8 (U.S. EPA, 1989a). GSD values typically range from 1.30 to 1.50 with an average (for the studies listed) of 1.42, a value which happened to match the GSD found in the NHANES II study, and thus the value chosen as default for the model. Table 9 shows how choice of a GSD affects soil cleanup levels.

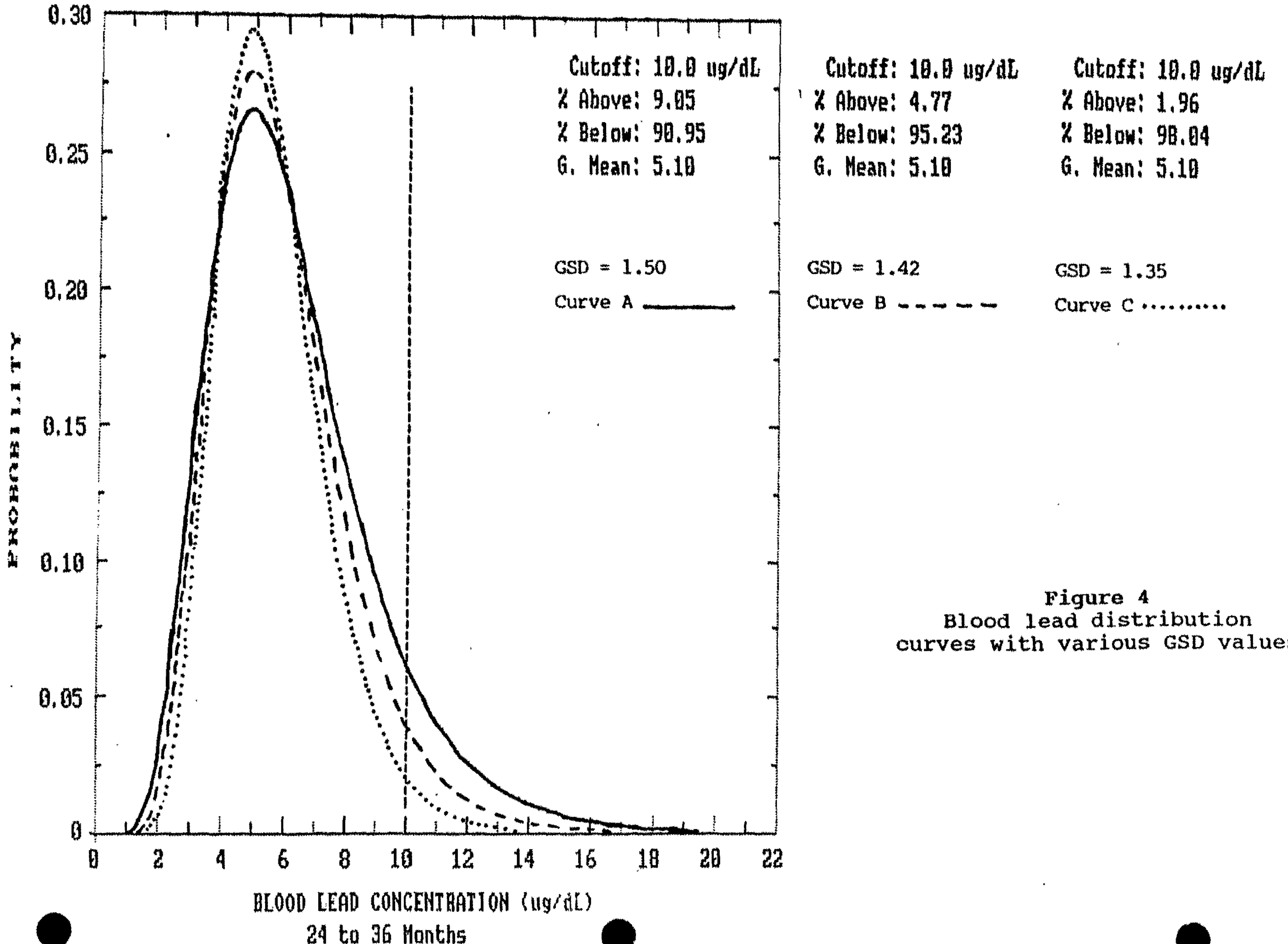


Figure 4
Blood lead distribution
curves with various GSD values

Table 8

Comparison of estimated GSDs across several studies

Population/Reference	Mean PbB (ug/dL)	Estimated GSD
NHANES II - total mix of children 1-5 years old (Schwartz, 1985)	16.0	1.42
11-year olds living near Belgian primary lead smelter (Roels et al., 1980)	21.7	1.29
1-9 year olds living near Idaho primary lead smelter (Yankel et al., 1977)	56.5	1.32
1-5 year olds, closest to 3 non-ferrous smelters in U.S. (Hartwell et al., 1983)	15.6 (median)	1.39
1-5 year olds, living near Montana primary lead smelter (CDC, 1983)	9.4	1.53
1-5 year olds, living in 3 Missouri smelter towns (Baker et al., 1977)	16.2	1.57

Method for estimating GSD found in Cohen (1986) and Marcus (1988).

Table 9

Soil clean-up levels required under different PbB GSD's:

	GSD					
cutoff PbB	1.3	1.4	1.5	1.6	1.7	1.8
10	480	375	280	205	140	85
15	835	670	535	420	325	245

all default but 1990 diet values; 95 % of population below cutoff

Model Validations

Several validation exercises on the original biokinetic model developed by OAQPS have been completed in which predicted and observed blood lead levels of children living near point sources of lead were compared. The most extensive study used 1983 data for 400 children ages 1-5 living near a lead smelter in East Helena, Montana. Using site-specific data as input into the model, the actual and predicted mean blood lead values were identical for children living within 2.25 miles of the smelter (U.S. EPA, 1989a). Using predicted soil and dust levels, as a test of the model when site specific data are missing, the model predicted a blood lead value of 9.5 ug/dL whereas the observed mean value was 9.3 ug/dL. Other validations in Omaha, Nebraska, and Kellogg, Idaho, were less extensive, but support the East Helena finding that the model performs well in predicting mean blood lead levels in children living near point sources of lead (U.S. EPA, 1989a).

The current ECAO version of the biokinetic model is essentially the same as the original OAQPS model, but several of the parameters have been changed to more conservative values as seen in Table 10. The current model is being used at the large Bunker Hill Superfund Site in Idaho to determine appropriate cleanup levels for soil lead. Validations of the model were made for the years 1983 and 1989 using site-specific data including soil, dust, diet, air, and water lead concentrations as well as site-specific soil ingestion/absorption values and GSD values. This validation exercise found that the model over-predicted PbB levels using the model default values for soil ingestion and absorption so site specific dose coefficients (the product of the absorption value and ingestion rate) were run rather than default values. These dose coefficients were determined by linear regressions of the mean PbB levels against reciprocal clearance rates (which are the PbB response coefficients determined by Harley and Kneip and diagrammed in Figure 1). The dose coefficients, determined in this manner, were 14.9 mg/day (1983) and 10.4 mg/day (1989) and would be equivalent to soil ingestion rates of 50 mg/day (1983) and 35 mg/day (1989) if the soil absorption value were assumed to be 30% (model default), or they would be equivalent to absorption rates of 15% (1983) and 10% (1989) if soil ingestion rates were assumed to be 100 mg/day (model default). Figures 5 and 6 (U.S. EPA, 1990) show plots of actual and model predicted PbB values for children less than 9 years old and less than 3 years old. This study concluded that the model can accurately predict mean blood lead response from various media given appropriate site-specific input parameters (U.S. EPA, 1989b, U.S. EPA, 1990).

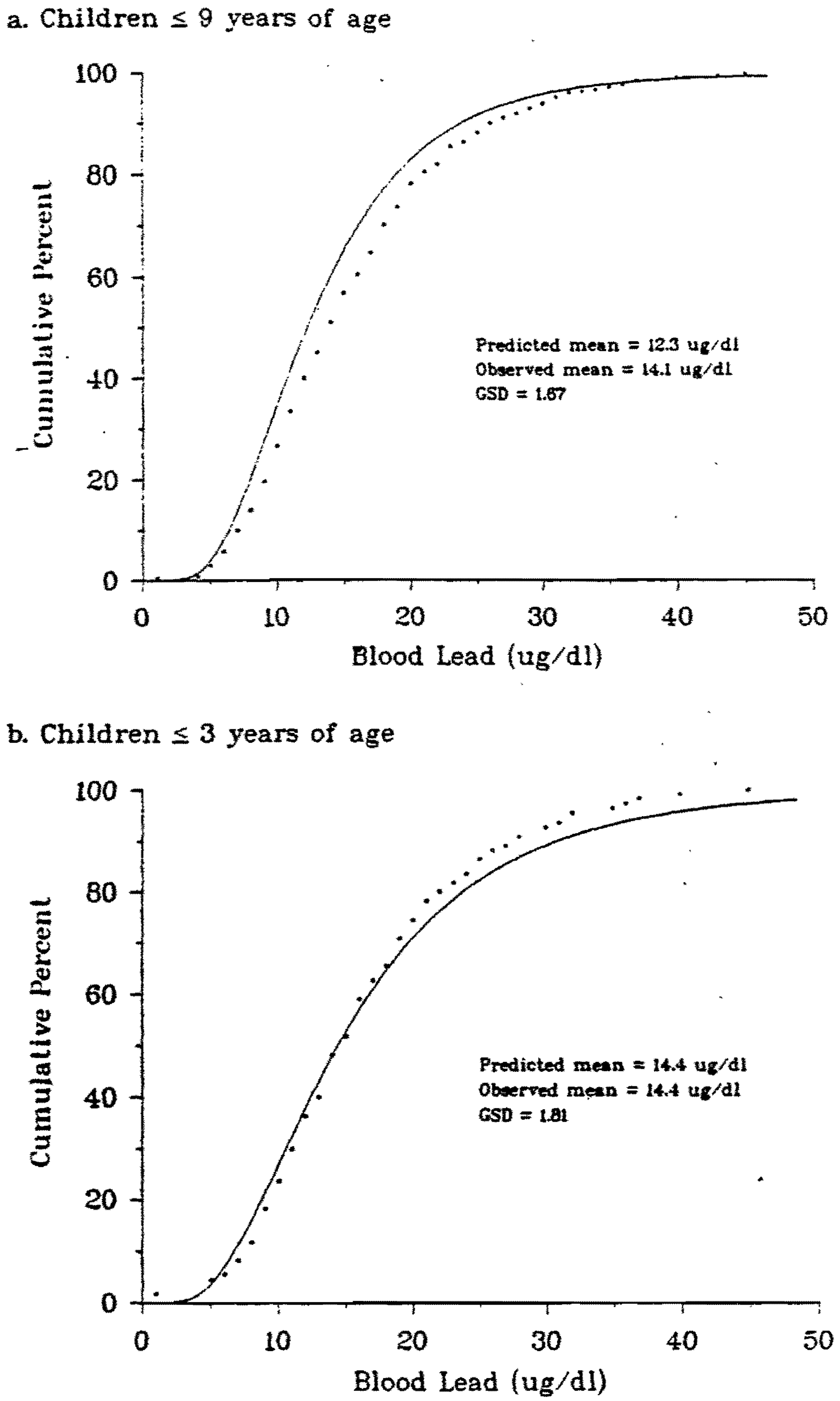
Table 10

Comparison between the original OAQPS parameters and the current ECAO lead model parameters

		OAQPS Input Parameters		Current ECAO Model	
Dietary Intakes:	Age	ug Pb/day	Abs. Value	ug Pb/day	Abs. Value
	0-1		42-53%	21.86	50%
	1-2	19.3	42-53%	25.94	50%
	2-3	24.1	30-40%	28.71	50%
	3-4	23.0	30-40%	20.05	50%
	4-5	22.0	30-40%	29.53	50%
	5-6	23.2	30-40%	31.10	50%
	6-7		18-24%	34.26	50%
Soil/Dust Ingestion:	Age	mg/day	Abs. Value	mg/day	Abs. Value
	0-1	0-85	25%	100	30%
	1-2	80-135	25%	100	30%
	2-3	80-135	25%	100	30%
	3-4	80-135	25%	100	30%
	4-5	70-100	25%	100	30%
	5-6	60-90	25%	100	30%
	6-7	55-85	20%	100	30%
Soil/Dust Partition Factor		25/75		45/55	

Figure 5
Bunker Hill Site

Comparison of 1983 Observed Childhood Blood Lead Distributions to Those Predicted by Integrated Uptake/Biokinetic Dose-Response Model*

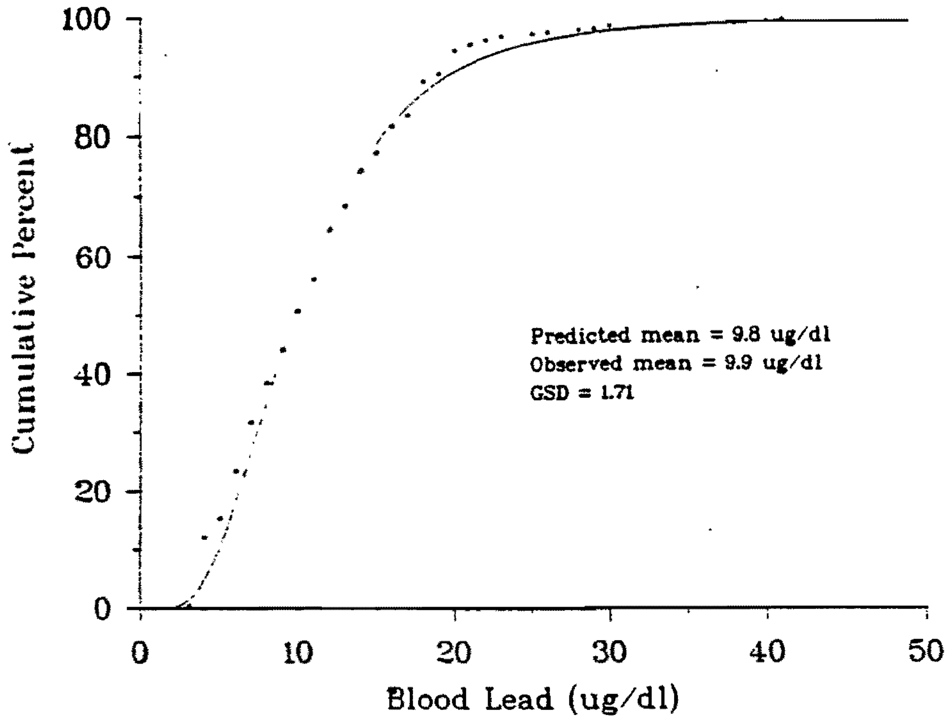


* Line represents predicted distribution and discrete points represent observed data.

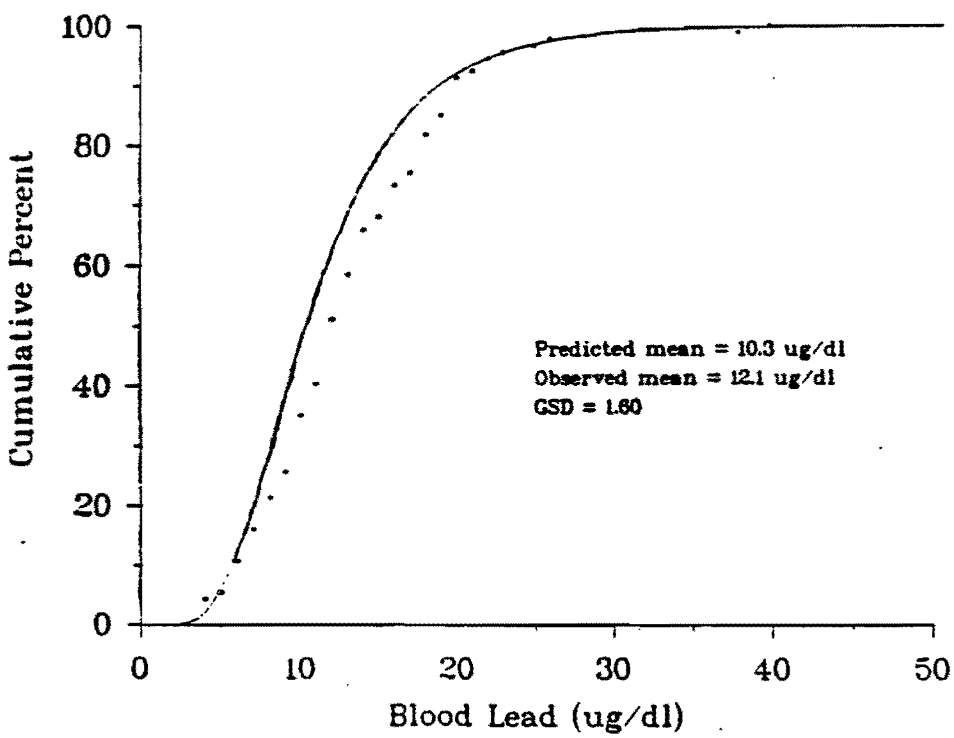
Figure 6
Bunker Hill Site

Comparison of 1989 Observed Childhood Blood Lead Distributions to Those Predicted by Integrated Uptake/Biokinetic Dose-Response Model*

a. Children ≤ 9 years of age



b. Children ≤ 3 years of age



* Line represents predicted distribution and discrete points represent observed data.

Current Applications

The most recent version of the model, Lead3, has been sent out to the regions for use on a trial basis. Regions III, VIII and X are currently using the model to make soil cleanup decisions. Without guidance as to what is an appropriate PbB cutoff level or what percentage of children should be protected, each region has been using the model in different ways. Region VIII, for example, is considering using a cutoff PbB level of 12.5 ug/dL and setting soil lead levels so that 95% of children have PbB levels below this value. Using site specific GSD values and the 1990 predicted diet values (Cohen, 1988a,b), the model sets soil/dust lead levels at from 440 to 480 ppm, so a level of 500 ppm has been recommended to the project managers at three Superfund sites in the region. (Weis, 1990)

As mentioned above, Region X has been using the model at the Bunker Hill site. No decisions have been made at that site as to what percentage of children should be above what cutoff PbB value, though extensive efforts have been put forth to analyze replacement soil requirements necessary to achieve various levels of soil remediation (U.S. EPA, 1990).

Region III has several sites contaminated with lead and they are considering soil cleanup levels as low as 150 ppm. These levels were set using 1983 diet values and using a cutoff PbB level of 10 ug/dL and keeping 95% of children below that level. The region has also considered using a GSD of 1.70, a value seen in the PbB distribution for children in the Baltimore Lead Study, along with the more current 1990 diet values which would still require soil cleanup in the 150 ppm range (Brunker, 1990).

Next Steps

***Further scientific tuning?** The IU/BK Model can be easily modified through changes in the default parameters. The default parameters for dietary intake, for example, should be updated as soon as the most current FDA values are available. Other important parameters of concern such as the soil/dust ingestion rate and absorption value can be modified based on future studies. The present model does not take into account factors which may influence the bioavailability of the soil/dust lead in a given area such as the chemical species of the lead or the particle sizes of the soils/dusts involved; once the nature of such characteristics is better understood, appropriate changes could be made in the model.

***Further validations to current model?** Changes in the default parameters of the model are continually being made; these changes can make the model better or worse at predicting the reality of PbB levels. Validation exercises comparing model predictions to actual PbB levels are the only true way of determining the success of the model. Given the changes to the original OAQPS model detailed above, are further validations to the current model needed or not?

***Seek SAB approval?** The Scientific Advisory Board (SAB) reviewed the original OAQPS model and approved its use in establishing air lead levels for the NAAQS. Should such approval be sought for the current model for use to establish soil cleanup levels? Given the adversarial context in which the model would be used at Superfund sites, review of the model by the SAB might be a benefit.

***Need for a policy decision.** A policy decision must be made concerning which population is to be protected and what percentage of that population will be protected below what PbB cutoff level.

***Other forms of the IU/BK model** At least two forms of the IU/BK model for lead are available. One form, a user friendly version like Lead3, is meant to be fairly fixed so that changes to the model itself are difficult to make, though it would be frequently updated; this keeps the less-than-expert user from making changes that distort the reality of the model's predictions. A second version, designed for the expert, is both flexible and powerful; it would be used by researchers familiar with the inner workings of the model to tinker with and test various parameters (Marcus, 1990).

***SEGH model** Another model has been introduced by the Soil Lead Task Force of the Society for Environmental Geochemistry and Health (SEGH) to determine acceptable concentrations of lead in soil. The principle disadvantage of this model is that it requires that both soil lead levels and blood lead levels be measured before cleanup levels can be determined; the need for such resource intensive data not only makes evaluations expensive, but it limits the model's ability to predict PbB levels for future scenarios. An option would be to have the SEGH model and the IU/BK model validated simultaneously at the same site so that the two could be appropriately compared (Wixson, 1990; Beck et al., 1990).

***Nature of ORD'S support for model?** Does ORD support the use of the model as it currently exists for use at Superfund sites? Would they provide technical support? Would they provide support during litigation?

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Appendix E

Glossary and List of Acronyms and Abbreviations

GLOSSARY

Acceptable Daily Intake. The amount of toxicant, in mg/kg body weight/day, that will not cause adverse effects after chronic exposure to the general human population.

Acceptable Intake for Chronic Exposure. The highest human intake of a chemical, expressed as mg/kg/day, that does not cause adverse effects when exposure is long term (lifetime). The AIC is usually based on chronic animal studies.

Acceptable Intake for Subchronic Exposure. The highest human intake of a chemical, expressed mg/kg/day, that does not cause adverse effects when exposure is short term (but not acute). The AIS is usually based on subchronic animal studies.

Ambient. Environmental or surrounding conditions.

ARARs. Applicable or relevant and appropriate requirements.

Background Exposure. Exposure under conditions offsite and in unimpacted areas.

Baseline Exposure. Exposure under onsite conditions with no remediation (no-action scenario.)

Bioaccumulation. The retention and concentration of a substance by an organism.

Bioconcentration. The accumulation of a chemical in tissues of an organisms (such as fish) to levels that are greater than the level in the medium (such as water) in which the organism resides (see bioaccumulation).

Cancer. A disease characterized by the rapid and uncontrolled growth of aberrant cells into malignant tumors.

Carcinogen. A chemical which causes or induces cancer.

Chronic Daily Intake. The projected human intake of a chemical averaged over a long time period, up to 70 years, and expressed as mg/kg/day. The CDI is calculated by multiplying long-term by the concentration human intake factor, and it is used for chronic risk characterization.

Chronic Exposure. Long-term, low level exposure to a toxic chemical.

Chronic. Occurring over a long period of time, either continuously or intermittently; used to describe ongoing exposures and effects that develop only after a long exposure.

Collocated. Set side by side.

Concomitant. To accompany or to be concurrent.

Dermal Exposure. Contact between a chemical and the skin.

Dermal. Of the skin; through or by the skin.

Dose-Response Assessment. The second step in the toxicity assessment process which involves defining the relationship between the exposure level (dose) of a chemical and the incidence of the adverse effect (response) in the exposed populations.

Dust. Airborne solid particles, generated by physical processes such as handling, crushing, grinding of solids, ranging in size from 0.1 to 25 microns.

DWEL (Drinking Water Equivalent Level). A DWEL is a medium-specific (i.e., drinking water) lifetime exposure level, assuming 100 percent exposure from that medium, at which adverse, noncarcinogenic health effects would not be expected to occur. The DWEL is derived from the multiplication of the RfD by the assumed body weight of an adult and divided by the assumed daily water consumption of an adult.

Endangerment Assessment. A site-specific assessment of the actual or potential danger to public health, welfare or the environment from the threatened or actual release of a hazardous substance or waste from a site. The endangerment assessment document is prepared in support of an enforcement action under CERCLA or RCRA.

Environmental Fate. The destiny of a chemical after release to the environment; involves considerations such as transport through air, soil and water, bioconcentration, degradation, etc.

Etiologic Agent. An agent responsible for causing disease.

Exposure Assessment. One of the components of the endangerment assessment process. The exposure assessment is a four-step process to identify actual or potential routes of exposure, characterize populations exposed and determine the extent of the exposure.

Exposure Scenario. A set of conditions or assumptions about sources, exposure pathways, concentrations of toxic chemicals and populations (numbers, characteristics and habits) which aid the investigator in evaluating and quantifying exposure in a given situation.

Fugitive Releases. Emissions that occur as a result of normal plant operations due to thermal and mechanical stress. Fugitive dusts may result from vehicle reentrainment, soil movement by earth-moving equipment, or wind erosion of contaminated surfaces.

Hazardous Waste. Hazardous waste, as defined in Title 40 of the Code of Federal Regulations, is a legal rather than a scientific term. To be considered hazardous, a waste must be on the list of specific hazardous wastestreams or chemicals, or it must exhibit one or more of certain specific characteristics including ignitability, corrosivity, reactivity and toxicity. The definition excludes household waste, agricultural waste returned to the soil and mining overburden returned to the mine site. It also excludes all wastewater discharged directly or indirectly to surface waters.

High Risk Child. Those children possessing several of the following risk co-factors observed to influence blood lead levels. Soil/dust ingestion rates are 90 to 100 mg/day for this group. Associated risk co-factors for classification are: a) chewing of finger-nails and mouthing of objects; b) nonvegetated or uncovered outdoor play area; c) poor quality housekeeping or high indoor dust levels; d) lack of dietary vitamin supplements; e) smoking parent in home; f) <$10,000 per year home income; and g) parents possess less than a secondary level of education.

Long-Term Concentration. The projected chemical concentration at an exposure point averaged over a long time period, up to 70 years (assumed to be a human lifetime). The LTC for the 70-year period beginning with the date of the RI/FS is used for carcinogenic risk characterization. Unless stated otherwise, the LTC refers to a best estimate concentration value, not an upper-bound estimate.

Lowest-Observed-Adverse-Effect Level. The lowest dose of a chemical in a study that produces statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and an appropriate control.

Mean. A statistical estimate of central tendency. Two different means are employed here: arithmetic mean and geometric mean. Arithmetic means approximate data centroids when data is normally distributed. Geometric means approximate data centroids when data is log-normally distributed. Arithmetic Mean $\geq$ Geometric Mean for the same data population.

Mutagen. An agent that causes a permanent genetic change in a cell other than that which occurs during normal genetic recombination.

Mutagenicity. The capacity of a chemical or physical agent to cause permanent alteration of the genetic material within living cells.

National Market Basket Variety Produce. Vegetable, fruit and meat produce distributed nationally and available on supermarket shelves, which constitutes the source of food for the average consumer.

NHANES. National Health and Nutrition Examination Survey, conducted in the U.S. and included interviews to obtain demographic, medical history, and nutritional information. Medical examinations and numerous laboratory measurements from blood and urine specimens, including blood lead determination, were also included. NHANES II was conducted from February 1976 to February 1980, with a probability sample of 27,801 persons residing in 64 areas of the United States.

No-Observed-Adverse-Effect Level (NOAEL). That dose of a chemical at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and an appropriate control.

No-Observed-Effect Level (NOEL). That dose of a chemical at which there are no statistically or biologically significant increases in the frequency or severity of effects between the exposed population and an appropriate control.

Pathway. A history of the flow of a pollutant from source to receptor, including qualitative descriptions of emission type, transport, medium and exposure route.

Pb-B. Abbreviation for blood lead concentration, usually expressed as μg Pb/dl of whole blood.

Pharmacokinetics. The dynamic behavior of chemicals inside biological systems; it includes the processes of uptake, distribution, metabolism and excretion.

Pica. Refers to both normal mouthing and subsequent ingestion of nonfood items, which is quite common among children at certain ages, and the unnatural craving for and habitual ingestion of nonfood items. The latter is an uncommon condition that is generally associated with medical conditions such as malnutrition, certain neuro-behavioral disorders, and iron deficiency anemia or, less often, with a particular cultural background.

Plume. Term used to describe the distribution of contaminants.

Population at Risk. A population subgroup that is more likely to be exposed to a chemical, or is more sensitive to a chemical, than is the general population.

Qualitative. Descriptive of kind, type or direction, as opposed to size, magnitude or degree.

Quantitative. Descriptive of size, magnitude or degree.

Risk Assessment. A qualitative or quantitative evaluation of the environmental and/or health risk resulting from exposure to a chemical or physical agent (pollutant); combines exposure assessment results with toxicity assessment results to estimate risk.

Risk Characterization. The final component of the endangerment assessment process which integrates all of the information developed during the exposure and toxicity assessments to yield a complete characterization of the actual or potential risk at a site.

Route of Exposure. The avenue by which a chemical comes into contact with an organisms (e.g., inhalation, ingestion, dermal contact, injection).

Scenario. A set of assumption describing how exposure takes place. Scenarios are usually constructed in the "Integrated Exposure Analysis" section of an exposure assessment and are usually specific to an exposure setting.

Short-Term Concentration. The projected chemical concentration in an exposure medium over a short-time period (10 to 90 days). The peak STC (i.e., highest concentration projected over the entire evaluation period) is used for subchronic risk characterization. Unless otherwise stated, the STC refers to a best estimate concentration value, not an upper-bound estimate.

Standard Deviation. A statistical estimate of variability associated with a data population. One standard deviation about the mean includes 68% of the data population, and two standard deviations about a mean includes 95% of the population.

Sub-chronic Daily Intake. The projected human intake of a chemical averaged over a short time period, expressed as mg/kg/day. The SDI is calculated by multiplying the short-term concentration by the human intake factor, and it is used for subchronic risk characterization.

Sub-chronic. Of intermediate duration, usually used to describe studies or levels of exposure between 10 and 90 days.

Teratogenesis. The induction of structural or functional development abnormalities by exogenous factors acting during gestation. Interference with normal embryonic development.

Teratogenicity. The capacity of a physical or chemical agent to cause nonhereditary congenital malformations (birth defects) in offspring.

Time-Weighted Average. The average value of a parameter (e.g., concentration of a chemical in air) that varies over time.

Toxicity Assessment. One of the components of the endangerment assessment process, the toxicity assessment is a two-step process to determine the nature and extent of health and environmental hazards associated with exposure to contaminants of concern present at the site. It consists of toxicological evaluations and dose-response assessments for contaminants of concern.

Toxicity Profile. A summary of the available human health or environmental toxicity data on a contaminant. This document considers doses used, routes of exposure, types of adverse effects manifested, and definitive statements of quantitative indices of toxicity.

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ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
ACL	Alternate Concentration Limit
Ag	Silver
AIC	Acceptable Intake for Chronic Exposure
AIRS	Aerometric Information Retrieval System (USEPA)
Al	Aluminum
ALA	Aminolevulinic acid
ALA-D	Aminolevulinic Acid Dehydrase (Dehydratase)
AQCD	Air Quality Criteria Document (USEPA)
ARAR	Applicable or Relevant and Appropriate Requirement
As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
Ba	Barium
Be	Beryllium
BEI	Biological Exposure Index
Bl-Pb	Blood Lead Level; also as Pb-B
Ca	Calcium
CAA	Clean Air Act
CaEDTA	Calcium Ethylenediaminetetraacetate
Cd	Cadmium
CDC	Centers for Disease Control
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CIA	Central Impoundment Area
CNS	Central Nervous System
Co	Cobalt
CPF	Cancer Potency Factor
Cr	Chromium
CTV	Critical Toxicity Value
Cu	Copper
CWA	Clean Water Act

D	Dose
DI	Daily Intake
DWEL	Drinking Water Equivalent Level
EA	Endangerment Assessment
ECG	Electrocardiogram
EECA	Engineering Evaluation and Cost Analysis
EEPC	Engineering Evaluation for Phased Cleanup
ELV	Estimated Limit Value
EP	Erythrocyte Protoporphyrin
EPTox	Extraction Procedure Toxicity
FDA	U.S. Food and Drug Administration
Fe	Iron
FEP	Free Erythrocyte Protoporphyrin
FWQC	Federal Water Quality Criteria
GCI	General Cognitive Index
GRC	Gulf Resources and Chemical Corporation
HAD	Health Assessment Document
HEA	Health Effects Assessment
HEED	Health and Environmental Effects Document
HEEP	Health and Environments Effects Profile
HIF	Human Intake Factor
IDAPA	Idaho Administrative Procedure Act
IDHW	Idaho Department of Health and Welfare
IRIS	Integrated Risk Information System
K	Potassium
kHz	Kilohertz
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDI	Mental Development Index
Mg	Magnesium

Mn	Manganese
MPF	Medium Partition Factor
MRL	Minimal Risk Level
Na	Sodium
NAAQS	National Ambient Air Quality Standard
NCP	National Contingency Plan
NEV	Nerve Conduction Velocity
NHANES	National Health and Nutrition Examination Survey
Ni	Nickel
NJHD	New Jersey State Health Department
NOAEL	No Observed Adverse Effect level
NOEL	No Observed Effect Level
NPL	National Priority List
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
OSHA	U.S. Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PANORAMAS	Pacific Northwest Regional Aerosol Mass Apportionment Study
Pb	Lead
Pb-B	Blood Lead Level
PHD	Panhandle Health District
PD	Protocol document=Human Health Risk Assessment Protocol for the Populated Areas of the Bunker Hill Superfund Site (Jacobs Engineering et al., 1989)
PDI	Physical Development Index
PEL	Permissible Exposure Limit
PHRED	Public Health Risk Evaluation Database
ppb	Parts per billion
ppm	Parts per million = μg/gm = mg/kg
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery act
RDA	Recommended Daily Allowance
RfD	Reference Dose

RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
Sb	Antimony
SDWA	Safe Drinking Water Act
Se	Selenium
SES	Socioeconomic Status
SFCDR	South Fork of the Coeur d'Alene River
SMCL	Secondary Maximum Contaminant Level
SPHEM	Superfund Public Health Evaluation Manual
TBC	To-Be-Considered
TCF	Time Correction Factor
TCLP	Toxicity Characteristic Leaching Procedure
TES	Technical Enforcement Support
Tl	Thallium
TLV-TWA	Threshold Limit Values - Time Weighted Average
TSCA	Toxic Substance Control Act
TSD	Treatment, Storage and Disposal Facility
TSP	Total Suspended Particulate Matter
TWA	Time Weighted Average
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
V	Vanadium
Zn	Zinc

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